# Storage Systems Qualification Manual

**DOCUMENT IDENTIFIER:** A-MN-ELEN522-01-0000 Rev C, 18-Sep-1991

**ABSTRACT:** This document establishes guidelines for storage and information systems qualification to be followed by all Product Management Teams and Qualification Teams for all Storage products, from components to systems, including clusters and distributed systems.

**APPLICABILITY:** This document applies to all products and services marketed by Digital Equipment Corporation, including new products designed and/or manufactured by Digital and its suppliers and value engineered products manufactured by Digital and Digital's suppliers.

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# 1 INTRODUCTION

In the development, production, and servicing of new products, each major milestone is marked by a phase transition. During each phase, and at each phase transition (see Figure 1), questions are asked and decisions are made relative to the quality or sufficiency of the items, processes, or products under development or production. The gathering of the information necessary to make informed decisions as to whether the product requirements and specifications are being met is termed the *qualification process*.

## 1.1 PURPOSE

This document is intended to provide product qualification guidance for product development teams. Many of the sections of this qualification manual may be used in *Six Sigma* methodology (see Figure 2). The document is not intended to be a detailed set of mandatory steps, but reliable advice from past experience. It should be used to meet the requirement to develop a comprehensive qualification plan (see subhead 1.3.4). This document provides the tools needed to set up product management and qualification teams, to develop the qualification plan, and to gather the information necessary for efficient and effective decision making.

## 1.2 SCOPE

This document is applicable to all Storage products requiring qualification. Products requiring qualification are new, ECOed, or value-engineered products manufactured by Digital or by its suppliers.

Products covered by this manual include the following.

- Integrated circuits (IC) components
- Non-IC components
- Hardware systems, subsystems, subassemblies, accessories, and supplies
- Software operating systems and layered products
- Distributed systems

## Figure 1: Qualification Process

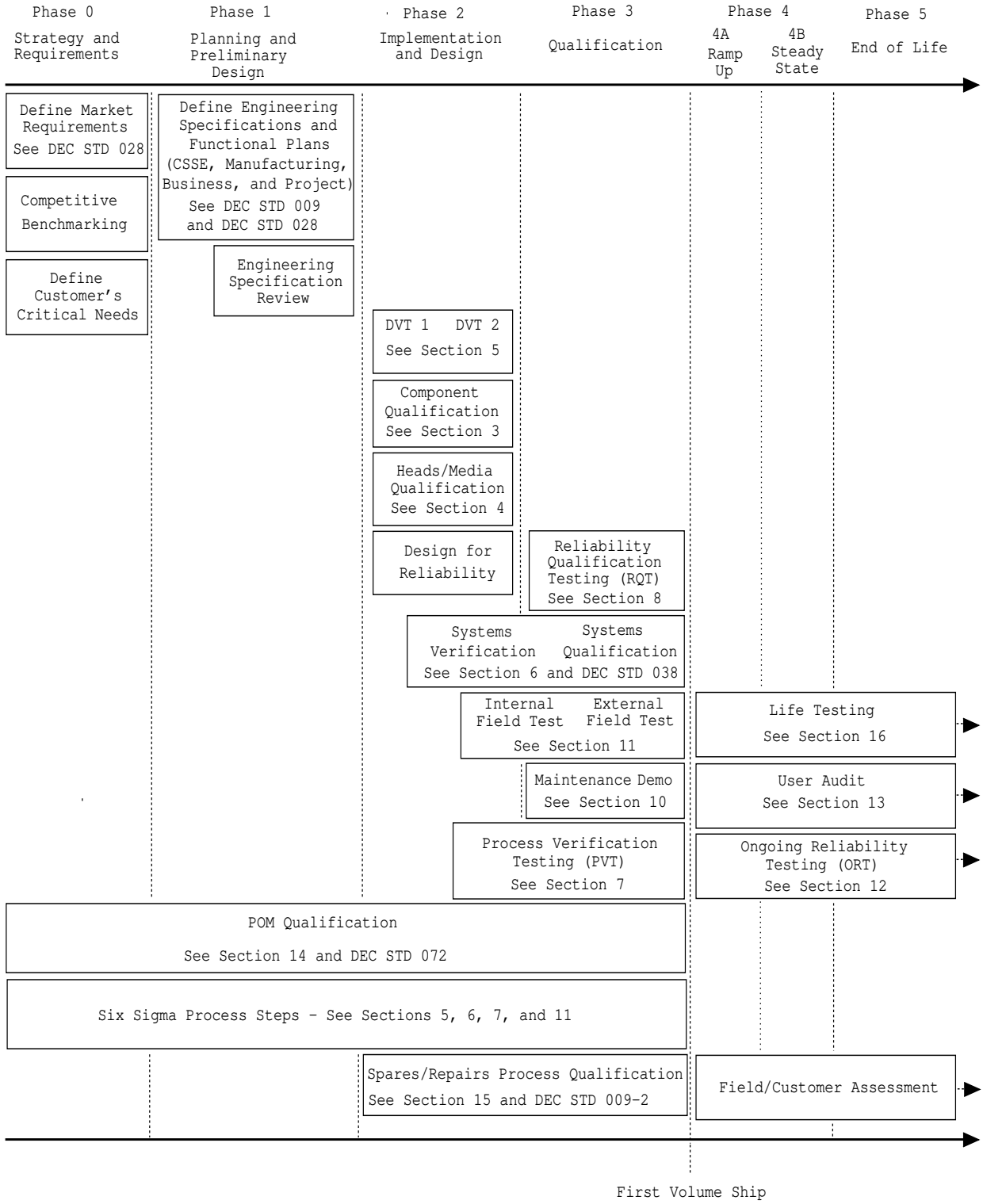


**Figure 2: Steps to ± Six Sigma**

1. Identify the product characteristics that are critical to satisfying both the physical and functional requirements of the customer and the relevant regulatory agencies.

2. Determine the specific product elements that contribute to achieving the critical characteristics.

3. According to product elements, determine the process step or choice that controls each critical characteristic.

4. Determine a nominal design value and the maximum (real) allowable tolerance for each critical characteristic that still guarantees successful required performance.

5. Determine the capability for parts and process elements that control the critical characteristics.

6. If Cp is not greater than or equal to 2 (Cpk greater than or equal to 1.5), then change the design of the product and/or process to achieve Cp greater than or equal to 2 (or institute process control measures that will narrow process capability sufficiently to achieve Cp greater than or equal to 2).

**NOTE**

**Refer to text under subhead 1.4 for definitions of the terms used in this figure.**

## 1.3 RESPONSIBILITIES

The following subheads define responsibilities related to product and process qualification.

### 1.3.1 PRODUCT MANAGEMENT TEAM

The Product Management Team is that team given the responsibility in *DEC STD 028-0 Phase Review Policy* for the total management of the new product development process. This includes the responsibility for ensuring:

- That customers have been identified and have been surveyed to determine their critical needs.
- That Competitive Benchmarking has been performed to determine the attributes of the best in the industry at supplying products that meet these critical needs.
- That a Product and Engineering Specification has been written that identifies the critical characteristics that are required to satisfy the customer.
- That the product delivered meets all the requirements so defined and satisfies all product quality requirements.

For Qualification purposes, this team is comprised, minimally, of the product manager, the program manager, the product engineering manager, the manufacturing manager, and the appropriate CSSE manager. Either the product or program manager will be the team leader.

The Product Management team is expected to comply with the guidelines of DEC STD 028-0 and other corporate policies, such as those developed by the Pricing and Announcement Committee (PAC). For qualification, the team's activities and responsibilities include the following.

- Establish the Qualification Team and designate the members. See subhead 1.3.2.
- Provide a schedule and prioritized information to the Qualification Team, prototype material, and other required resources for the successful implementation of the qualification process.
- Receive qualification information and risk assessments from the Qualification Team, and provide the Qualification Team with input, feedback, and guidance.

The Product Management Team must have consistent membership from Phase 0 through Phase 4b.

### 1.3.2 QUALIFICATION TEAM

The Qualification Team is a cross-functional team responsible for assisting the Product Management Team with the development of the Qualification Plan and the implementation of the total qualification test program for a new product.

This team must have consistent membership from Phase 0 through Phase 4b.

The Qualification Team will consist of one member from each of the organizations represented on the Product Management Team, but as a minimum, Design Engineering, Manufacturing, CSSE, Product Management, and Product Assurance (Quality) shall be represented.

The Qualification Team shall manage the qualification portion of product development. The distinction between the Qualification Team and a test implementation team should be noted. While members of the Qualification Team may be actively involved in one or more phases of testing, individual test teams will be formed to implement the various phases of testing that are separate from, but report to, the Qualification Team.

The Qualification Team manages the planning, testing, analysis, and reporting for each testing procedure, which includes the following.

- Draft the Qualification Plan in response to Product Management Team guidance and for Product Management Team approval.
- Review and approve each plan before testing begins.
- Review periodic summaries of test data.
- Determine and review the classification of failures.
- Review plans for corrective action on failures.
- Determine test status.
- Determine test termination (halt or successful completion).
- Assess and document risks to facilitate decision making.
- Establish a unified data collection system for all problem reporting.

The Qualification Team is formed during Phase 0 of the Phase Review Process. The Engineering Development Manager is responsible for calling together the Product Management Team to identify the Qualification Team members. The Product Management Team is responsible for reviewing the qualifications of and approving all proposed Qualification Team members.

### 1.3.3 CHAIRMANSHIP AND MANAGEMENT EXCEPTION AND ESCALATION

Chairmanship of the qualification team should be assigned to the Qualification Team member directly involved with the majority of qualification testing evolutions. Typically, this will be Product Assurance. Test teams for events such as maintainability demonstrations, plant Ongoing Reliability Testing (ORT), field test, and so forth, may have few if any members of the Qualification Team as active participants, but the Qualification Team will still retain the responsibility outlined in subhead 1.3.2 relative to the test.

At the conclusion of the various phases of testing (Reliability Qualification Test [RQT], Design Verification Test [DVT], and so forth), the Qualification Team must formally and unanimously agree to complete each test.

The Qualification Team is responsible for reporting test status, risk assessments, and their recommendations to the Product Management Team on a periodic and timely basis. In the event that the Qualification Team does not agree on a course of action or the risk assessment as related to one of the product quality requirements, both opinions must be presented in writing, including alternative solutions, to the Product Management Team.

### 1.3.4 QUALIFICATION PROCESS REQUIREMENTS

Product requirements should be based on Competitive Benchmarking and the customer's critical needs. The Qualification Process is the process defined to ensure that requirements specified for a product are met and that the corporation's customers will be satisfied. The Qualification Plan is the combination of strategy and tactics developed to define and implement this process. The Qualification Plan should include requirements to ensure that:

- Specifications are approved at all levels (IC components, non-IC components, hardware systems and subassemblies, software operating systems, and layered products, media, distributed systems, operations, and so forth) by appropriate key functions (Engineering Development, Customer Services, Manufacturing, Product Manager, Program Manager, Quality, and Software).
- New product functionality is thoroughly examined and verified.
- Applicable Digital standards are met.
- Product reliability is verified at all levels (IC components, non-IC components, Hardware systems and subassemblies, software operating systems, and layered products, distributed systems, media, and so forth).
- Manufacturing process (and *Six Sigma*) goals and metrics are met.
- Manufacturing processes are in control and producing products that meet all aspects of the product specification.
- The product is verified to meet or exceed competitive market requirements, and it is verified by customers to meet or exceed their expectations.
- Qualification is linked to the Phase Review Process so that well-defined milestones are met prior to each phase transition. Similarly, key qualification milestones, required by PAC for announcement and First Revenue Shipments (FRS) of new products, are met.
- A formal management exception and escalation process is defined to be used if any of the above items has not been completed to the satisfaction of the entire Qualification or Product Management Teams.
- The product specific qualification process be efficient as possible while providing sufficient information to be effective in the decision making process. Past product experience and efficiencies in testing should be used as much as possible.
- Cause and effect diagrams are created for each subassembly and then summed to evaluate the impact to the customer.
- Failure Mode and Effects and Critical Analysis have been performed.

**NOTE**

**An important objective for management and qualification teams is the need to eliminate duplication of effort and redundant testing and to optimize time-to-market. If a product is going to be subjected to the same standards test many times (for example, option level and system level) there would be an opportunity for the qualification and management teams to agree on a plan that would eliminate the redundancy. However, in doing so, the teams must take care to move such testing to earlier in the process rather than later whenever possible.**

## 1.4 DEFINITIONS

**Cp —** Maximum Allowable Range of Characteristic divided by Normal Process Variation: Cp = (Upper Specification Limit (USL) - Lower Specification Limit (LSL))/Six Sigma)

**Cpk—** Cp times *(1—k)*, where k is the shift of the mean divided by one-half the Upper Specification Limit minus the Lower Specification Limit:
Cpk = Cp x [1—((target mean—process mean)/.5 (USL-LSL))]

**Design for Reliability (DFR) —** A generic term used to emphasize the need to address the reliability of the product as one of the singularly most important aspects of the product specification.

**Design Verification Testing (DVT) —**

- *DVT-1:* Theoretical DVT — A paper and pencil design assessment, analysis, and improvement process.
- *DVT-2:* Empirical DVT — The effort in design of experiments, margining, *test-til-it-breaks*, Digital Standard testing, reliability growth testing, and so forth.

**Beta Field Test —** Testing of final design units in a user environment, usually at external Digital customer sites.

**Alpha Field Test —** Testing of prototypes in a user environment within Digital. The prototype unit used for internal testing typically is not the final design and may not contain all attributes required by the specification.

**Maintainability Demonstration Testing (MDT) —** Assessment of the maintenance characteristics and adequacy of the service support structure.

**Ongoing Reliability Testing (ORT) —** A continuous reliability assessment of production units.

**Process Verification Testing (PVT) —**

- *PVT—1:* Theoretical PVT — The paper and pencil prototype process design and verification effort.
- *PVT—2:* Empirical PVT — Analysis of process capability, development of learning curve experience, and assessment of time-to-burn-in.

**Reliability Growth Test (RGT) —** A design engineering tool to enhance the reliability of a product using the test-analyze-fix methodology.

**Reliability Qualification Testing (RQT) —** Assessment of whether the product meets the reliability requirement.

**Systems Verification Testing (SVT) —** The efforts by systems groups and storage groups to verify that the system requirements for storage options are sound and will be achieved by the design.

# 2 SPECIFICATION REVIEW

The Specification Review ensures that the Market Requirements Document is based upon detailed competitive market analysis, benchmarking, and real customer requirements.

The Specification Review ensures that Customer and Market requirements, as specified in the Market Requirements Document, have been correctly and completely translated into Engineering Specifications.

The Specification Review ensures that the resultant specifications:

- Are traceable back to the specific Customer and Market requirements
- Are expressed in known measurable terms
- Permit subsequent detailed product qualification

## 2.1 PREREQUISITES

In order to conduct the specification review, the following documents and information must be available, and controls in place, as indicated.

- Market Requirements Document
- Product Requirements Document
- Customer Services Plan (preliminary)
- Phase 1 Business Plan completion
- Manufacturing Plan
- Detailed Product/Process Specification
- Specifications are under document control
- Competitive analysis report
- Benchmarking data available for critical product process attributes

## 2.2 RESPONSIBILITIES

The New Product Qualification Team is responsible for arranging and conducting the Specification(s) Review. In particular they should ensure sufficient cross-functional participation such that:

- The voice of the internal and external customer has clear representation.
- Area specific aspects have been integrated.
- Engineering and Manufacturing are aware of the relative importance of the individual specification aspects.
- Customer Services plans are an integral part of the system plans.

## 2.3 REQUIREMENTS

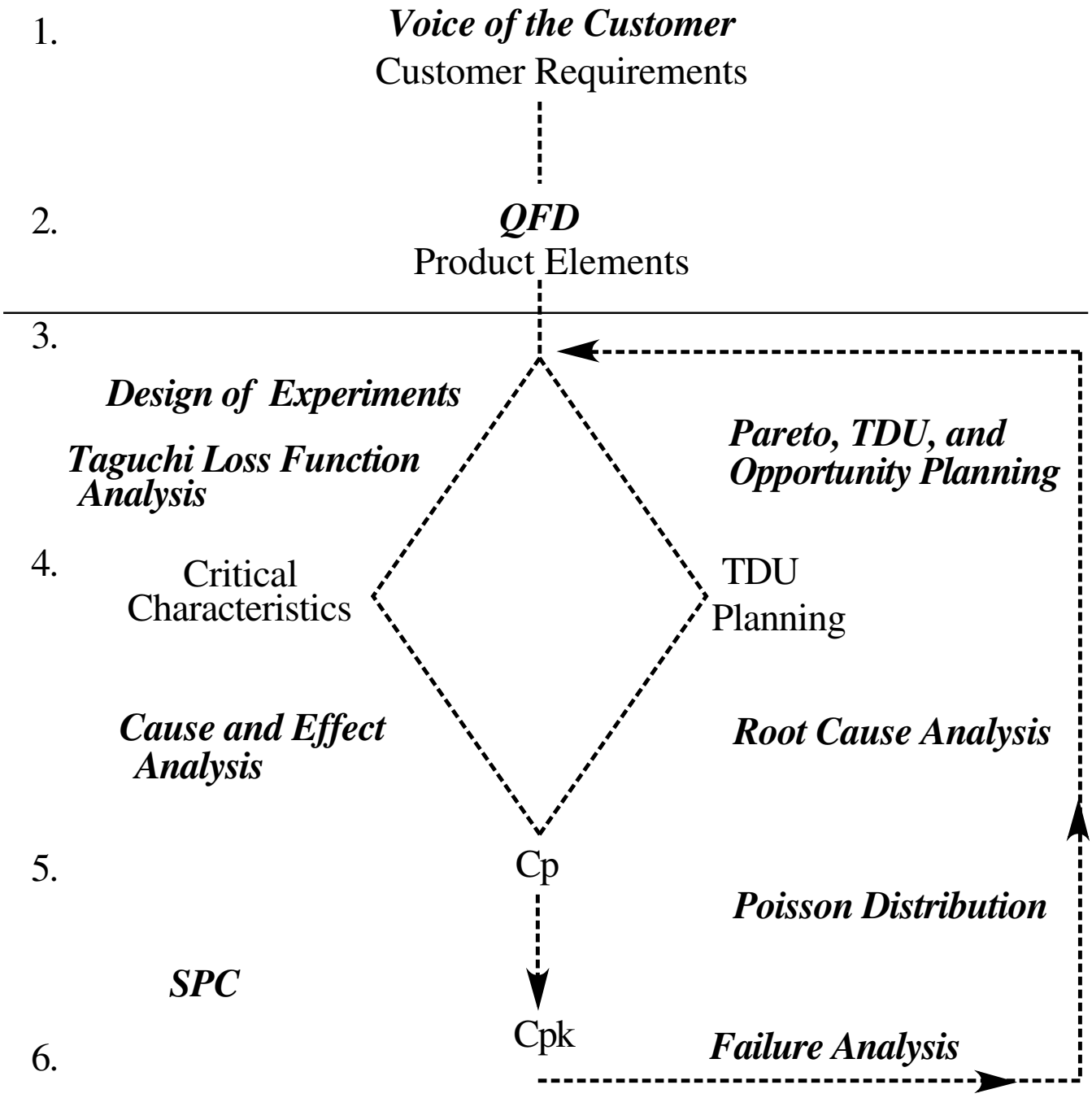
The specification review shall ensure that the product specification has been developed using the *Six Sigma* methodology, and that it is complete. Key elements of the review are to ensure that:

- Each specific key competitive product aspect is documented as part of the specific market requirements.
- Each specific market requirement has been clearly documented and translated into detailed product specifications.
- A critical characteristic matrix is created.
- Each detailed product specification is measurable or that a plan exists to achieve measurability.
- Each detailed product specification is quantifiable.
- A *Six Sigma* Plan including a prediction of defects per unit (DPU) must be completed. The following needs to be completed to accurately predict DPUs:
  - — Engineering and manufacturing will meet to determine a list of critical components and critical tolerance stackups.
  - — Engineering will calculate the theoretical Cp for all criticals components and tolerance stackups, and will present the Cps at a *Six Sigma* Readiness Review prior to completion of DVT.
  - — Manufacturing will use the date from the readiness review to predict FRS TDU and *Six Sigma* levels. These predictions are necessary for Phase 1 exit.
- Applicable standards have been defined and, where standards need to be changed or created, a plan exists to achieve this.

**NOTE**

**As design activities for product and process progress, opportunities for defects and TDU plans and predictions will be updated to reflect new or recent data. Results will be compared to FRS TDU and *Six Sigma* levels, and those areas with high opportunities and/or DPUs should be targeted for further analysis, and if possible, significant reductions (see Figure 3). Templates, definitions, assumptions, and guidelines used will be in accordance with those established throughout Storage Systems.**

**Figure 3: SIX SIGMA—Method and Tools**



## 2.4 APPLICABLE DOCUMENTS

### Applicable Digital Standards

### Digital Environmental and Safety Standards

*DEC STD 102-0 Environmental Standard for Computers and Peripherals—General Test Requirements*
*DEC STD 103-0 Electromagnetic Compatibility (EMC)—Overview and Process Requirements*
*DEC STD 104-0 Product Acoustic Noise Limits*
*DEC STD 119-0 Digital Product Safety—Introduction and General Requirements*

### Digital Design Standards

*DEC STD 002-0 AC Power Wiring, Safety Earth Grounding, Plugs and Receptacle Information and Requirements*
*DEC STD 005-0 Operational Alert (OPAL) Procedure*
*DEC STD 009-1 Product Engineering Specifications: Electrical, Physical, and Environmental Parameters*
*DEC STD 009-2 Product Engineering Specifications: Reliability, Availability, and Maintainability Parameters*
*DEC STD 030-0 Module Manufacturing Standard—Introduction and General Information*
*DEC STD 032-0 VAX Architecture Standard*
*DEC STD 038-0 System Evaluation of New Products— General*
*DEC STD 052-0 Operational Requirements for Serial Terminals and Computer Interfaces Operating as DTEs Connected to EIA RS-232-C or CCITT V.28 Modems*
*DEC STD 056-0 Circuit Diagrams and Item Designations - General Requirements*
*DEC STD 057-0 VAXBI Standard*
*DEC STD 060-0 Design of Hardware Products to National and International Regulations and Standards, Policies and Procedures*
*DEC STD 062-0 Product Submittal to Regulatory Agencies*
*DEC STD 091-0 Product RAMP Requirements*
*DEC STD 120-0 Product Thermal Design Standard: Design Requirements*
*DEC STD 122-0 AC Power Line Standard: Design Requirements and Guidelines*
*DEC STD 123-0 Power Control Bus Standard*
*DEC STD 158-0 Unibus Specification—Design Specification*
*DEC STD 160-0 LSI-11 Bus Specification—Design Specification*
*DEC STD 161-0 Computer Interconnect Specification*
*DEC STD 178-0 Digital Identification Marking Requirements - Introduction*
*DEC STD 186-0 Signal Integrity*

## 2.5 COMPLETION CRITERIA

The result of the specification review, as it pertains to the new product, is a report published by the Qualification Team that states that all specifications are complete, accurate, measurable, and under document control.

# 3 NEW IC AND NON-IC COMPONENT QUALIFICATION

New IC and non-IC components must meet certain requirements for qualification. This heading specifies qualification requirements for new IC and non-IC components, other than heads and media. For heads and media qualification, see heading 4.

Non-IC components are defined in subhead 3.2 and includes all part classes other than 19-, 20-, 21-, and 23-class components.

## 3.1 PREREQUISITES

The following shall be completed or available in preliminary form before the component qualification process begins.

- Part Number Request Form (PNRF)
- Purchasing or Engineering specification
- Supplier Qualification
- Functional Assessment of application-specific components
- Component Qualification Plan
- Sourcing Plan
- Identification of high risk components

## 3.2 DEFINITIONS

**class —** Identification of a part by Part Identifier Class Code per *DEC STD 012-2 Unified Numbering Code for Part Identifier Class Codes.*

**component qualification plan —** A detailed method for accomplishing the qualification of a component. The plan describes the proposed or tentative project or goal in a step-by-step format.

**functional assessment —** An in-depth study to determine that a component is capable of performing, or can be adapted to perform, a particular design purpose.

**Functional Class Descriptor (FCD) —** A descriptor for functionally similar components regardless of part class (for example: fuses can be in both Class 12 and Class 90).

Class Descriptor — Components:

Class 10 — Capacitors
Class 11 — Diodes, rectifiers, LED, and so forth
Class 12 — Electromechanical, mechanical devices
Class 13 — Resistors
Class 15 — Transistors
Class 16 — Transformers, chokes, delay lines
Class 17 — Cable products, fiber optic cable assemblies, wire harness products.
Class 18 — Crystals, self-contained oscillators
Class 19 — LSI bipolar

Class Descriptor — Components (continued):
Class 20 — Hybrids
Class 21 — LSI MOS
Class 23 — LSI programmable
Class 37 — Labels
Class 48 — Metal stock
Class 49 — Adhesive products
Class 50 — Raw boards
Class 70 — Wired assemblies
Class 74 — Machined or fabricated
Class 90 — Hardware
Class 91 — Wire
Class 99 — Packaging, shipping materials

Exceptions (to this section):

Class 14 — Printed Circuit Boards (see headings 4—17)
Class 22 — Supply Kits (see heading 10)
Class 30 — Major Peripheral Outside Buys (and some Media) (see heading 17).

**high risk components —** Components that require special attention to meet the FRS goal due to component complexity, limited sources, critical product functionality, schedule pressures, resource limitations, and similar unique characteristics.

**Part Number Request Form (PNRF) —** Form used to initiate the qualification of a new component.

**specifications, Purchasing or Engineering —** Any Purchasing or Engineering Specification document, in released or preliminary form, used to describe the component to be qualified.

**sourcing plan —** A detailed description that addresses the overall procurement plan of action, including a needs assessment resulting in sourcing proposals and associated risks, the sourcing strategy, and the tactics for achieving an optimum supplier for the component.

**supplier qualification —** Supplier satisfactorily meets the requirements of *EL-MF347-00, Ship-to-Stock Supplier Qualification Program—Audit Guideline for Plant Quality Engineer*, System Audit section and applicable portions of the Process Audit schedules.

### 3.3 RESPONSIBILITIES

The responsible Component Engineer shall establish a component Qualification Team by product or commodity, consisting of the following functions.

- Component Engineering (plant/group) — Convenes the component Qualification Team and provides leadership for qualification activities.
- Purchasing — Interfaces with all suppliers during the qualification process.
- Manufacturing — Evaluates manufacturing compatibility.
- Design Engineering — Evaluates design compatibility.

The component Qualification Team is responsible for the completeness, technical content, and implementation of the qualification plan and strategy. The Component Engineer, who has signatory authority for a product or commodity, is responsible for component qualification.

### 3.4 REQUIREMENTS

Specific requirements must be defined in the Component Qualification Plan. In addition to verifying that the component meets its specifications, the Plan should address the *Six Sigma* objectives of the Corporation by including:

- Repeatability study — Using one sample of the component being qualified, have several individuals repeat the measurement of key parameters using the defined measurement process and equipment. Verify that the mean and standard deviation of the measurement difference meets the error budget requirements for the component.
- Develop components' Cp and Cpk — Using components from a stable process, measure the key component parameters and calculate the Cp and Cpk for these components' values. Ensure that the values meet the required program objectives.

Component qualification is considered complete when the component meets:

- The specification as written or as modified
- The functionality requirements of product application
- Manufacturing volume criteria and business needs

A component reaches the *Completion Endpoint* when it has been rated Q (qualified) on the corporate Specifications on Computer (SPOC) database.

### 3.5 REFERENCE STANDARDS, DOCUMENTS, AND PROCEDURES

*DEC STD 085-0 Component Qualifications—Requirements to Support Phase Review Process*, and applicable Digital, industry and agency standards. Also relevant are the Six Steps to Six Sigma for Engineering and Manufacturing (see Figure 2).

# 4 HEADS AND MEDIA QUALIFICATION PROCESS

This process applies to all heads and media (Digital or supplier design) used in Storage System produced products.

## 4.1 PREREQUISITES

The following shall be completed or available before the heads and/or media qualification process begins.

- PCO Released Engineering Specifications are complete.
- The Design Verification Tests (DVTs) are tests designed to ensure that the product's electrical, mechanical, environmental, and magnetic design requirements have been met. These tests include an initial assessment of the part reliability with emphasis on wear, materials analysis, parametrics, and mechanics.
- Preliminary Electrical and Mechanical Heads and Media Standards are complete.
- Qualification Plan is approved by the Product Qualification Team and the Product Management Team as part of the Phase 1 activities.
- Assessment of supplier capability for buy-out product is complete.
- Heads and Media Manufacturing Processes are released and controlled by Statistical Process Control (SPC) techniques and at Cpk levels that support *Six Sigma* objectives.
- The Heads/Media Qualification Team is established.
- The capability exists to perform failure analysis for problem definition.
- Qualification status milestones and review schedule are established.

## 4.2 RESPONSIBILITIES

The following is a list of the responsibilities for the planning, technical guidance, approval, and implementation of the qualification process.

- The Heads and Media Qualification Team shall consist of representatives from heads and media design engineering, drive design engineering, heads and media Manufacturing (quality), and/or supplier engineering.
- The team is responsible for the overall completeness and technical content of the Qualification Plan. They shall ensure (and advise the individual plants of) the appropriateness of all tests for heads media, and the head disk assembly (HDA). The team shall ensure that the tests are coordinated to achieve maximum efficiency and integration of the qualification process.
- Second source qualification is the responsibility of Manufacturing (leadership role) with Design Engineering approval.

## 4.3 REQUIREMENTS

The qualification process for heads and media recognizes the need for multiple-level integration of activities at the head, media, and HDA (or drive) levels and encompasses the following.

- Qualification Tests (specification compliance). See Table 1.
- Process Verification Testing (PVT). See PVT, heading 7.
- Establishment of the Ongoing Evaluation (Reliability Assessment) Plan (subset of items in Table 1).

Through various testing techniques and accelerated stress testing, potential problem areas can be identified and corrected prior to the drive level qualification process.

After qualification, heads and media will continue to be subjected to accelerated stress testing in an ongoing evaluation process to verify parametric integrity, long term reliability, and manufacturing process control.

Qualification and ongoing evaluation tests will be performed at multiple levels (for example, component, subassembly, and HDA) with the intent of ensuring all applicable specifications are met. Final acceptance will be based upon the ability of the heads and media to meet the total product specification in addition to their respective component specification requirements.

The limits for the tasks defined in Table 1 are specified by the applicable design specifications.

## Table 1: Heads and Media Qualification Test Requirements

| | TYPE TESTS | DISK HEADS | DISK MEDIA | HDA | TAPE HEADS | TAPE MEDIA | OPTICAL MEDIA |
|---|---|---|---|---|---|---|---|
| 1 MECHANICAL | | | | | | | |
| 1.1 STATIC | | | | | | | |
| Visual Mechanical Inspection | Q R | X | X | – | X | X | X |
| Critical Dimensions | Q R | X | X | – | X | X | X |
| Bond Strengths | S Q R | X | – | – | X | X | – |
| Surface Characteristics | Q R | X | X | – | X | X | – |
| 1.2 DYNAMIC | | | | | | | |
| Glide | Q R | – | X | – | – | X | – |
| Flying Characteristics | Q R | X | – | – | – | – | – |
| Resonances | Q R | X | – | X | X | X | – |
| Mechanical Fatigue | S Q R | X | – | – | – | – | – |
| Reflectivity | A R | – | – | – | – | – | X |
| 2 ELECTRICAL/OPTICAL | | | | | | | |
| 2.1 PARAMETRIC(S) | Q R | X | X | X | X | X | – |
| 2.2 FUNCTIONAL | | | | | | | |
| Error Rates | Q R | – | – | X | – | – | X |
| Defect Mapping | Q R | – | X | X | – | X | – |
| Phase Margin | Q R | – | X | X | X | X | – |
| 3 MAGNETICS | | | | | | | |
| 3.1 PARAMETRIC(S) | Q R | X | X | – | X | X | – |
| 3.2 MAGNETIC AGING | Q R | X | – | X | X | X | – |
| 3.3 MAGNETIC ERASURE | Q R | X | – | X | X | X | – |
| 4 TRIBOLOGY | | | | | | | |
| Friction | Q R | X | X | X | X | X | – |
| Start/stop | Q R | X | X | X | X | X | – |
| Parametric changes (4F amp) | Q R | X | X | X | X | X | – |
| Wear | S Q R | X | X | X | X | X | – |
| 5 LUBE PARAMETRIC(S) | Q R | – | X | – | – | – | – |

Key:

S = Stress Test
Q = Qualification
R = Reliability
X = Applicable
- = Not applicable

**Table 1 (Cont.): Heads and Media Qualification Test Requirements**

| | TYPE TESTS | DISK HEADS | DISK MEDIA | HDA | TAPE HEADS | TAPE MEDIA | OPTICAL MEDIA |
|---|---|---|---|---|---|---|---|
| 6 ENVIRONMENTAL | | | | | | | |
| 6.1 NON-OPERATING | | | | | | | |
| Chemical sensitivity | Q R | X | X | X | X | X | – |
| Corrosion | S Q R | X | X | X | X | X | – |
| Vibration/mechanical shock | Q R | X | – | X | X | X | X |
| Temperature/humidity | Q R | X | X | X | X | X | X |
| Electrostatic Discharge (ESD) | Q R | X | X | X | X | X | X |
| 6.2 OPERATING | | | | | | | |
| Corrosion | S Q R | X | X | X | X | X | – |
| Vibration/mechanical shock | Q R | X | – | X | X | X | X |
| Temperature/humidity | Q R | X | – | X | X | X | X |
| 7 DURABILITY, LONG AND SHORT | Q R | – | – | – | – | X | – |
| 8 PERFORMANCE OF MEDIA ENCLOSURE | | | | | | | |
| Tolerance Stackup | S Q R | – | – | – | – | X | X |
| Materials analysis | S Q R | – | – | – | – | X | X |
| Shock and vibration | S Q R | – | – | – | – | X | X |
| 9 PACKAGING | S Q | X | X | X | X | X | X |

Key:

S = Stress Test
Q = Qualification
R = Reliability
X = Applicable
- = Not applicable

## 4.4 RECOMMENDED TOOLS

The following are tools that may be used for machine characterization and correlation and the determination of performance parameters using data obtained during the qualification process.

- The use of these tools or methods, which may depend upon known acceleration and stress factors. Until these factors are known and available, ongoing testing for reliability shall be used to ensure process and product quality consistency.
- The Machine Capability and Correlation Procedure.

## 4.5 COMPLETION CRITERIA

For completion of the heads and media qualification process, the following actions are required.

1. The Qualification Team ensures the generation of the Final Heads or Media Qualification Report. This report includes:
   - Qualification Plan, test results, problems, and corrective action
   - Pass/fail summary of qualification results
   - Recommendations
   - Risks
2. The ongoing heads and media evaluation plans are completed and approved by Design Engineering, including the assessment requirements for proposed product and/or process changes.
3. Heads/Media Engineering and Manufacturing management review and approve the Final Qualification Report.

The heads and media qualification process and critical corrective actions must be completed prior to the FRS of the final product (drive) for the first heads or media vendor, and prior to additional vendor parts being shipped for subsequent vendors.

# 5 DESIGN VERIFICATION TESTING

The Design Verification Test (DVT) should follow a time line congruent with the Corporate phase planner —

- DVT-1 completed before Phase 1 exit.
- DVT-2 completed before Phase 2 exit.

DVT is the portion of the qualification test process established to develop the proposed product design that supports the business goals and meets the product engineering specifications, and that verifies compliance with applicable Digital design standards. It is divided into two portions, DVT-1 and DVT-2.

DVT-1 is referred to as the theoretical analysis phase and should be done within both Design Engineering and Manufacturing Engineering. In this Phase the product engineering-manufacturing group must do a joint, concurrent product-process design. The goal is full compliance with product requirements and a resulting Cp value of equal to or greater than 2.

DVT-2 is the actual hardware, software, and firmware testing of the engineering breadboard and/or prototype units and subassemblies. The DVT-2 test plan should emphasize the test-to-break philosophy so design and material margins can be fully assessed.

## 5.1 DVT-1 PREREQUISITES

- DVT-1 Plan
- An appropriate competitive analysis or benchmarking has been completed.
- Market Requirements Document that verifies the product specifications and design meet customer and market expectations and requirements
- Preliminary Business Plan that verifies the product specification and design support all appropriate business goals for the product
- Program or Project Plan that verifies that the specifications and design are consistent with schedule and project cost goals
- Preliminary Product Functional and Engineering Specifications
- Manufacturing Phase 0 Impact Statement
- Customer Service Phase 0 Impact and RAMP Requirements Document

## 5.2 DVT-2 PREREQUISITES

To ensure a successful test sequence, the following prerequisites should be met.

- DVT-1 started and progress is being monitored by Qualification Team
- Formal design review for hardware, software, and firmware
- DVT-2 Test Plan
- Specifications, schematics, and drawings under Preliminary Change Authorization (PCA) control

### 5.3 DVT-1 AND DVT-2 REQUIREMENTS AND RESPONSIBILITIES

Tables 2 and 3 list requirements and responsibilities for DVT-1 and DVT-2.

Documentation review: familiarize, understand, and compare all relevant project documentation. The review typically includes, but is not limited to, the requirements and responsibilities listed in Table 2.

The DVT-2 requirements and responsibilities, listed in Table 3, are the points that the DVT-2 Test Plan should minimally address.

**Table 2: DVT-1**

| REQUIREMENTS AND RESPONSIBILITIES | RESPONSIBLE FUNCTIONS | SUPPORTING FUNCTIONS |
|---|---|---|
| Compare the engineering specifications to the requirements of DEC STD 009-1 and *DEC STD 009-2 Product Engineering Specifications: Reliability, Availability, and Maintainability Parameters*. | P | E, C, M |
| Error specification | E | C, M |
| Error handling specification | C | E, M |
| Requirements document(s) | P | E, C, M |
| Detailed system requirements documents for multisystem peripherals and terminals | P | E, C, M |
| Business plan | P, M | E, C |
| Product cost structure review (does it meet goals?) | E, M | C |
| Schematic review, equations, flows, and so forth | E | M, C |
| Diagnostics plan, goals, specification | E | M, C, P |
| Reliability plan review | E | M, C, P |
| Design for Reliability and Reliability Apportionment | E, M | P |
| Project plan review | E | M, C, P |

Key:

E = Engineering
M = Manufacturing
C = CSSE
P = Product Management

**Table 2 (Cont.): DVT-1**

| REQUIREMENTS AND RESPONSIBILITIES | RESPONSIBLE FUNCTIONS | SUPPORTING FUNCTIONS |
|---|---|---|
| Part and technology availability and choices review | E, M | C |
| Preliminary timing review | E | M, C |
| Possible layout considerations review | E, M | C, P |
| Software interface specifications | E | M, C |
| Firmware specifications | E | M, C, P |
| Overall product specification | E | M, C, P |
| Product functional specification review for conformance to architecture specifications | E | M, C, P |
| Part list analysis | E, M | C |
| Component qualification status and vendor selection analysis | E, M | C |
| Parts stress analysis (including thermal) | E | M, C |
| Review of the reliability predictions, goals, stress analysis, recommendations for error detection and correction, and other fault tolerance and redundancy schemes | E | M, C |
| Preliminary Thermal Analysis (simulation) | E | M, C |
| Analysis of effects of humidity, altitude, vibration, shock, hazardous chemicals, and electrostatic, electromagnetic, and magnetic fields | E | M, C |
| Mechanical tolerance build up analysis, dissimilar metals | E, M | C |
| Logic and circuit simulation | E | M, C |
| Worst Case Timing Analysis | E | M, C |
| Analysis of power and signal distribution | E | M, C |

Key:

E = Engineering
M = Manufacturing
C = CSSE
P = Product Management

**Table 2 (Cont.): DVT-1**

| REQUIREMENTS AND RESPONSIBILITIES | RESPONSIBLE FUNCTIONS | SUPPORTING FUNCTIONS |
|---|---|---|
| Analysis of power allocation and consumption | E | M, C |
| Analysis of international features | P, C | E, M |
| Reviews plans or strategy for tools or equipment necessary to conduct DVT | E | C, M, P |
| Ease of assembly, fitness for use, manufacturability | M, E | C, P |
| Maintainability and human factors and testability | C, E | M, P |
| Review roll-up of process capability by part number (predict DPU) | M, E | P |
| DVT test software requirements | E | M, C |
| Generate DVT-2 Test Plan | E | M, C |
| Verify that all mechanical component dimensions can be manufactured by current high volume processes | M, E | - |
| Define the Opportunities for Errors in the Manufacturing process | M | E |
| Establish the FTY and DPU goals for each Program milestone | M | E |
| For each test in the manufacturing process, perform a Repeatability test to establish the mean and standard deviation of the measurement difference | M | E |
| While building the Prototype units, determine the Cp and Cpk for all non-PASS/FAIL tests in the manufacturing process | M | E |
| Measure the FTY and DPU for all prototypes built | M | E |

Key:

E = Engineering
M = Manufacturing
C = CSSE
P = Product Management

**Table 3: DVT-2**

| REQUIREMENTS AND RESPONSIBILITIES | RESPONSIBLE FUNCTIONS | SUPPORTING FUNCTIONS |
|---|---|---|
| Layout check for opens, shorts, extra etch, power and return connections, DEC STD 030-0 compliance | E, M | C |
| Layout rule check (DEC STD 186-0), signal integrity analysis | E, M | C |
| Electrical loading check of all ICs, discrete circuits and components, and I/A ports | E | M, C |
| Verification of diagnostic coverage, usefulness to user, and effectiveness (ease of use, system error recovery, and so forth) | C, E | M |
| Conformance to safety requirements, including flame retardation and controlling the use of toxic substances (DEC STD 119-0) | E | M, C |
| Proper airflow and filtration, cabling elegance, acoustics | E, C | M |
| Tolerance study | E | M, C |
| Acoustic analysis (DEC STD 104-0) | E | M, C |
| Power connections check | E | M, C |
| Power consumption check | E | M, C |
| Power sequencing check | E | M, C |
| Loadable diagnostic coverage, effectiveness, and ease of use verification; ease of system level fault isolation, error logging, and symptom directed diagnosis | C, E | M |
| Verification of on-board diagnostics and firmware | C, E | M |
| Verify consideration of human factors for both the user and the maintenance technician | C | E, M |
| Life test of critical components, cables and connectors, and subassemblies | E | M, C |

Key:

E = Engineering
M = Manufacturing
C = CSSE
P = Product Management

**Table 3 (Cont.): DVT-2**

| REQUIREMENTS AND RESPONSIBILITIES | RESPONSIBLE FUNCTIONS | SUPPORTING FUNCTIONS |
|---|---|---|
| Compliance with intended manufacturing assembly and test processes | M, E | C |
| ESD susceptibility emi/rfi testing (*DEC STD 062-2 German EMI Certifiction/Approval Process*, *DEC STD 067-0 Electrostatic Discharge - Sensitive Devices*,*DEC STD 103-0 Electromagnetic Compatibility (EMC) - Overview and Process Requirements*) | E | M, C |
| Power supply regulation | E | M, C |
| Voltage and temperature margining to fail points | E | M, C |
| Differential signal return and VCC noise measurements | E | M, C |
| Power up/down cycling and proper response | E, C | M |
| Clock variation test | E | M, C |
| Signal integrity verification under all worst case interface conditions (for example, cables at 1½ maximum specified length) | E | M, C |
| Empirical thermal analysis (for example, infrared scans, thermocouple, air flow transducers, and so forth) | E | M, C |
| Module capacitance measurement at all busses, internal and I/A | E | M, C |
| Functionality Testing: Timing, all software and hardware selectable features and functions tested. Special consideration should be given to the test and qualification of new critical components, interfaces of new technology to old technologies, and so forth. Error handling and recovery should also be included. | E, C | M |
| Cross-talk measurement | E | M, C |
| Electrical loading tests at I/A ports margined to fail points | E | M, C |
| Architecture verification: Tests for mocks, and other architecture SDI, SCSI, TMCP, DSSI | E | M, C |

Key:

E = Engineering
M = Manufacturing
C = CSSE
P = Product Management

**Table 3 (Cont.): DVT-2**

| REQUIREMENTS AND RESPONSIBILITIES | RESPONSIBLE FUNCTIONS | SUPPORTING FUNCTIONS |
|---|---|---|
| Interchangeability: Chip for chip, different vendors, module slot for module slot, media/drive for media/drive, write hot read cold, and so forth | E | M, C |
| Interoperability: System components communicate effectively without inducing degradation in the operation of another component (see heading 6) | E | M, C |
| Specifications, schematics, drawings under -PCO and ECO control | E, M | C |
| Design Margin testing to failure of critical parameters and components to determine or indicate the distributions of likely manufacturing variations and DPUs, stress and strength distributions, and critical design parameters | E, M | C |
| Measure FTY, TDU, Cp and Cpk for all units built | M | E |
| Verify the validity of the value and tolerance of key component characteristics. | M, E | – |
| Assemble components with characteristics at the specification extremes, and verify that the sub-system meets the functional specification. | M, E | – |

Key:

E = Engineering
M = Manufacturing
C = CSSE
P = Product Management

## 5.4 COMPLIANCE TO DIGITAL STANDARDS

Compliance to the following Digital standards shall be included in the DVT as appropriate.

- Verification of compliance with Digital Environmental and Safety standards *DEC STD 102-0 Environmental Standard for Computers and Peripherals—General Test Requirements*,
  *DEC STD 103-0 Electromagnetic Compatibility (EMC) - Overview and Process Requirements*,
  *DEC STD 104-0 Product Acoustic Noise Limits*, and
  *DEC STD 119-0 Digital Product Safety—Introduction and General Requirements*.

  Compliance with Digital design standards

- *DEC STD 002-0 AC Power Wiring, Safety Earth Grounding, Plugs and Receptacle Information and Requirements*,
  *.DEC STD 005-0 Operational Alert (OPAL) Procedure*,
  *DEC STD 009-1 Product Engineering Specifications: Electrical, Physical, and Environmental Parameters*,
  *DEC STD 030-0 Module Manufacturing Standard—Introduction and General Information*,
  *DEC STD 032-0 VAX Architecture Standard*,
  *DEC STD 038-0 System Evaluation of New Products—General*,
  *DEC STD 052-0 Operational Requirements for Serial Terminals and Computer Interfaces Operating as DTEs Connected to EIA RS-232-C or CCITT V.28 Modems*,
  *DEC STD 056-0 Circuit Diagrams and Item Designations—General Requirements*,
  *DEC STD 057-0 VAXBI Standard*,
  *DEC STD 060-0 Design of Hardware Products to National and International Regulations and Standards, Policies and Procedures*,
  *DEC STD 062-0 Product Submittal to Regulatory Agencies*,
  *DEC STD 091-0 Product RAMP Requirements*,
  *DEC STD 120-0 Product Thermal Design Standard: Design Requirements*,
  *DEC STD 122-0 AC Power Line Standard: Design Requirements and Guidelines*,
  *DEC STD 123-0 Power Control Bus Standard*,
  *DEC STD 158-0 Unibus Specification – Design Specification*,
  *DEC STD 160-0 LSI-11 Bus Specification—Design Specification*,
  *DEC STD 161-0 Computer Interconnect Specification*,
  *DEC STD 178-0 Digital Identification Marking Requirements—Introduction*,
  *DEC STD 186-0 Signal Integrity*, and any other applicable Digital standard.

  Refer to *Engineering Product Compliance Standards and Related Documents - Volume 2*, EL-SM457-02.

  The standards demonstrations may be completed by subsystems or systems and need not be duplicated at the option level.

## 5.5 DVT PROCESS MANAGEMENT

### 5.5.1 Test Plans and Reports

The Qualification Team is responsible for generating, monitoring, and in some cases changing the overall test plan. This test plan should address the following.

- Schedule and planned duration of specific test elements
- Human resources needed
- Test equipment and configuration(s)
- Special test environments (chambers, FCC test, and so forth) and duration needed
- Test sample: how many, who will build, upgrade plan, and documentation requirements
- Data collection and analysis
- Corrective action and Preliminary Change Order (PCO) process
- List of management team members who must review and approve the plan
- Periodic and final test reports for the program archive

### 5.5.2 General Process Guidelines

The Qualification Team chairman and the team are responsible for tracking progress, problems uncovered by the testing, and the status of corrective action. The following guidelines are useful tools for managing the process.

- The use of a formal tracking mechanism such as Failure Analysis Reporting (FAR) is strongly recommended.
- MIL-HDBK-781 *Reliability Test Methods, Plans, and Environments for Engineering Development, Qualification, and Production* (subhead 4.3)
- MIL-HDBK-189, *Reliability Growth Management*

## 5.6 TEST COMPLETION CRITERIA

- All items in the DVT checklist(s) are completed to the satisfaction of the Qualification Team and management team.
- Any custom items added to the checklist(s) by the Qualification Team are completed.
- At least one formal Design Review Meeting (DRM) is held. The DRM should be conducted at the end of DVT-1, or before the construction of prototypes begins. The reviewers should not be part of the immediate design team, but should be knowledgeable enough to critique the design. The review team should also have cross-functional representation.
- All action items resulting from the DRM are performed.

# 6 SYSTEM VERIFICATION TESTING (SVT)

Systems Verification Testing (SVT) determines that all facets of the product (normal operation, fault management, and availability options) perform as stated in the engineering specifications in the system and subsystems environment.

The Qualification Team is responsible for generating the SVT plan and executing it. The Product Management Team is responsible for approving the SVT plan.

Any device that has undergone a complete SVT should be able to be shipped to any customer, placed in any compatible environment, and operate according to the specification. Emphasis will be placed on doing test in actual supported (FRS) configurations.

SVT is applicable to all storage systems products.

## 6.1 SVT STRUCTURE

SVT testing is done in two separate stages. The first stage, performed when a usable product is produced, reports problems to design engineering as soon as possible. This stage is referred to as Proto SVT. The second stage verifies all testing and problems fixed in the first stage. This stage is referred to as Pilot SVT.

Each stage of SVT has two parts. The first part verifies functional portions of the device under maximum and minimum configurations and loads. This is called Functional Systems Verification. The second part is referred to as the Fault Management Systems Verification Test. This test is done by inserting faults on the device under different configurations and ensuring the proper responses of both the device and the systems under test. Both of these parts can run in parallel by first ensuring the functional portion works on a configuration, then allowing faults to be inserted under that configuration.

### 6.1.1 Functional Systems Verification Testing

This portion of SVT testing ensures that a system or device, operating as part of a system, operates as specified in different configurations using different power systems, operating systems, layered products, and loading schemes. The test configurations shall be formatted in a matrix for the SVT plan and shall include minimum, maximum, and typical configurations. The matrix will be used by the test team, with the help of product management, to determine the order of testing, prioritized according to those configurations that will be marketed first. The sample matrix in Table 4 provides space for two configurations.

**Table 4: Sample Test Matrix**

| Configurations: | 1 | 2 |
|---|---|---|
| Processor | | |
| Controller | | |
| Other Devices | | |
| Other Variables | | |
| Power System | | |
| Operating System | | |
| Test Software | | |
| Total Test Time (days) | | |

The following information shall be included in the matrix.

- Processor — The CPU driving the configuration.
- Controller — The controller used for test purposes.
- Other Devices — All other devices in the configuration. These are devices that may affect compatibility or performance of the device under test. This could include, but not be limited to, other devices on the same bus or multiple related devices.
- Other Variables — Other variables used within the configuration.
- Operating System — The operating system used under this configuration.
- Test software — Any user level programs used for the test. (This is the actual user level stimulus for any problems.) This software should be comprised of tests that create various levels of system and device loading, ensuring that all devices in the configuration are used and all other variables are brought into play. This ensures that the device will work as expected in any user environment.
- Total Test Time — Expected test duration.

### 6.1.2 Fault Management Systems Verification Testing

The second portion of SVT testing determines that the device is able to handle all errors as stated in the Error Handling Specification. To determine the effectiveness of the error handling for the device, a selected list of faults (including those that have the largest impact on reliability, performance, and highest probability of occurrence) should be inserted in different configurations (laid out in the test plan). Then the resulting recovery and reporting mechanisms should be verified for proper operation. Any fault not handled as stated in the Error Handling Specification shall be considered a problem and should be reported as a failure of SVT.

## 6.2 PROTOTYPE SVT

The Proto SVT is intended to identify and report problems to the design team for correction as early as possible in the product life. This gives the design team more time for problem correction and lowers the cost and impact of the needed regression testing, and also gives some level of confidence to the Qualification Team and Product Management Team as to what the product's performance will be in later stages of testing.

### 6.2.1 Prerequisites

The following are prerequisites for the Proto SVT.

- A functional prototype product is available for testing.
- The design is under PCO control.
- The prototype SVT plan is written and approved by the Qualification Team and the Product Management Team.

### 6.2.2 Testing

Proto SVT is begun by running functional tests, starting with the high priority configurations, as outlined in the test plan.

Once this portion of the SVT is running as expected, a subset of the faults for the Fault Management portion of the SVT on each configuration should be inserted on the device. Once all faults specified in the SVT plan are inserted and all problems reported, this stage of SVT is complete.

## 6.3 PILOT SVT

The Pilot SVT is the final testing performed before installing the device in a customer environment.

### 6.3.1 Prerequisites

The following are prerequisites for the Pilot SVT.

- All testing (*DEC STD 102-0 Environmental Standard for Computers and Peripherals—General Test Requirements*, DVT-1, DVT-2, and so forth) are completed to the satisfaction of the Qualification Team.
- The Pilot SVT Plan is written and approved by the Qualification Team and the Product Management Team.
- All product documentation is made available to the qualification team:

  Parts lists
  Flow diagrams
  Timing diagrams
  Schematics
  Module layouts
  Tolerance studies (maximum loads)
  Wiring diagrams
  Engineering specifications
  Error handling specifications

Technical manuals
Service manuals

- Requirements:

  The device is as similar to the shippable product as possible.
  All specifications are finalized and no changes are pending.
  The product is under ECO/PCO control.

### 6.3.2 Testing

Pilot SVT is the final test that ensures that all problems have been identified and viable solutions are in place.

This stage of the SVT is done in the same manner as Proto SVT, except that all faults should be inserted in all configurations. Specific emphasis should be placed on problems reported in the Proto SVT. This stage of the SVT cannot be considered complete until all problems reported in both the Proto SVT and Pilot SVT have been resolved and the solutions have proven acceptable. In so far as is possible, testing should be done on actual supported configurations.

## 6.4 REPORTING

Reporting is one of the most crucial portions of the test since this is the method of ensuring that all involved parties can determine how the product is performing. There are several stages of reporting, none of which can be left out without compromising the effectiveness of the test. All levels of reporting should be followed in both Proto and Pilot SVT.

**test logging** — A complete log of every facet of the SVT should be kept and archived at the end of the test. These logs should be used to determine the progress through the SVT test plan and after the test for postpartum reviews on product performance in the customer environment.

**error reports** — Any deviations of product performance from the stated performance in any specification should be reported as an error during the testing. This reporting should be reviewed on a regular basis by the test team to determine problem prioritization and severity, and to determine the status of problem fixes.

**memorandum** — All reports of progress on problem fixes should be given to the test team and product development team in the form of memos. Memos are appended to the final test report.

**final test report** — This report shall be generated at the close of SVT and distributed to all parties on the test team and the product development team. This report mentions, for every facet of the testing as stated in the test plan, a list of all problems found during the testing, a list of all fixes to those problems, and test process problems discovered during the testing.

## 6.5 COMPLETION CRITERIA

SVT shall not be considered complete until all steps of the test plan have been successfully completed and all problems found have been addressed and fixed. When all the problems have been fixed, a final regression test pass will be made to verify the fixes. The final test report must be written and on file with the Qualification Team and the Product Management Team.

# 7 PROCESS VERIFICATION TESTING (PVT)

Process Verification Testing (PVT) is the term that covers the design, maturation, and assessment of the manufacturing process. It is divided into two parts, PVT-1 and PVT-2, to distinguish between the paper research and design effort and the physical process development/traditional testing and analysis.

PVT-1, the *Theoretical* PVT, includes all those efforts that go into designing a process with a Cp > 2 (Cpk > 1.5). It includes the process capability studies based on past performance, current technology, and expected DPU from proposed process steps.

PVT-2, the *Empirical* PVT, includes the build and testing of a manufacturing process. It verifies that the process satisfies expectations of cost (capital and product), cycle time, quality levels and controls (DPU, reliability, and so forth), human resource requirements, initial burn-in requirements, and Statistical Process Controls (SPC).

## 7.1 PVT-1 PREREQUISITES

As a minimum, the following are prerequisites for PVT-1.

- Vendor management process is in place.
- Critical characteristics of the product have been identified.
- A PVT-1 plan of action is completed.

## 7.2 PVT-1 REQUIREMENTS

The goal of PVT-1 is to ensure that a logical program is followed and that every reasonable effort is made to design a process to meet *Six Sigma* objectives prior to any preproduction build.

The basic requirements for PVT-1 are that Engineering and Manufacturing must:

- Examine the critical characteristics of the product and design the product to meet these requirements, and ensure manufacturability.
- For each product element, determine the process step or process choice that affects or controls required performance.
- Determine maximum (real) allowable tolerance for each product element and process step.
- Determine the capability for parts and process elements that control required performance.
- Ensure Cp is greater than or equal to 2.
- *Six Sigma* TDU goals for all components and process steps have been established.

## 7.3 PVT-2 PREREQUISITES

As a minimum, the following are prerequisites for PVT-2.

- All manufacturing procedures are complete.
- Process specification is complete.
- All process steps are evaluated for process capability.

- Process design is understood and sufficiently advanced to allow a detailed analysis of the metrics.
- PVT-2 plan is approved by the Qualification Team and the Product Management Team.
- Producibility and testability analyses of the design are complete.
- Training for involved personnel is complete.
- Data collection and analysis system has been developed and approved by the Qualification Team.
- The team agrees that DVT has met the milestones agreed upon to proceed with the build verification portion of PVT.

### 7.4 PVT-2 REQUIREMENTS

PVT-2 is the procedure in which the process is implemented and matures. The following actions are included in PVT-2.

- All process steps are evaluated for process capability.
- An evaluation of the following is conducted.
  - — Total assembly and test time
  - — Process procedures and test coverage effectiveness
  - — Corrective action system effectiveness
  - — Projected DPU and other metrics as defined in the theoretical analysis
  - — Training effectiveness
  - — Cost
  - — Production capacity
  - — Time standards
  - — Safety procedures and their effectiveness
  - — In-process repair strategy and its impact on product quality and reliability
- Actual Cpk for each critical process attribute must be measured and reviewed by the Program team.
- DPU for all process steps must be measured and reported. Future DPU goals should be established.
- A closed-loop reporting and corrective action system must be in place. Manufacturing should repair all customer returns for a minimum of 1 year after FRS and ideally over the manufacturing life of the product so that accurate customer failure data can be obtained.
- For non-repairable FRUs a means of field return must be established to return failed units to the manufacturing plant for failure analysis.
- A customer TDU reporting system should be in place.
- An assessment of the following will be performed.

  Infancy characteristics
  Infancy removal techniques (may include environmental stress screening) and their effectiveness

Optimum burn-in duration (to the reliability specification or beyond)
Process control parameters for each major process step
Capacity versus DPU
Calibration effectiveness
Customer feedback requirements

## 7.5 RESPONSIBILITIES

The successful execution and completion of the Process Verification Testing part of the qualification process requires the active participation of many groups, most notably Manufacturing, Engineering, and CSSE. The following paragraphs highlight major responsibilities of these functions with respect to PVT.

### 7.5.1 Manufacturing

- Process Engineering
  - — Work with Design Engineering to design for manufacturability.
  - — Develop process specification.
  - — Design the "manufacturing process".
  - — Develop test strategy.
  - — Develop infancy removal strategy.
  - — Manage failure analysis to the root cause for failures during PVT.
  - — Manage process change control system.
  - — Document changes required as a result of PVT activity.
  - — Review and approve final test report.
- Production
  - — Review and approve PVT plan.
  - — Implement data collection and analysis system.
  - — Coordinate training on an ongoing basis.
  - — Implement process changes as identified during PVT.
  - — Review and approve final test report.
- Quality and Product Assurance
  - — Write the PVT plan.
  - — Chair the qualification/product team.
  - — Manage the corrective action activity during PVT, including obtaining solutions to product and process problems from other groups.
  - — Retain records.
  - — Obtain feedback from internal customers and correlate that with PVT results.
  - — Publish the final PVT report.

### 7.5.2 Design Engineering

— Review and approve the PVT plan.

— Design for manufacturability.

— Assist Manufacturing in developing the process specification.

— Assist Manufacturing in defining test strategy including configuration.

— Plan, coordinate, and implement corrective action of all latent design problems detected during PVT.

— Supply personnel to diagnose and correct repetitive/systematic failure modes.

— Review and approve final PVT report.

### 7.5.3 CSSE

— Review and approve the PVT plan.

— Provide timely feedback on field test and seed program performance (for example, problem-free installation, human factors, field test, and field performance history on related products).

— Help develop and implement in-process repair strategy.

— Monitor and feedback the effectiveness of corrective action.

— Understand and influence the field returns repair process as applicable.

— Establish a channel for feedback from all Customer Service Logistics (CSL) centers.

— Review and approve final PVT report.

## 7.6 RECOMMENDED TOOLS

There are several tools that can and should be used to evaluate process capability to produce a product. The following tools have been found to be useful in this step of the Qualification Process.

- HAZFIT — EL-EN036-04, *Hazard (Infancy) Analysis Specification*, is applicable in situations where an infancy phenomenon is expected. The program provides estimates of steady-state Mean-Time-Between-Failure (MTBF) and expected burn-in duration required to meet specified MTBF.

  To obtain the HAZFIT software, send electronic mail to CSSE::WHITTEMORE stating your intent to copy the files. This is to provide access and maintain security. Once access is granted, type:

  ```
  $ COPY CSSE::DISK$A6:[CSSEINFO.RAMP]HAZARD.BLD *.*
  ```

  At the system prompt, execute HAZARD.BLD by typing:

  ```
  $ @HAZARD.BLD
  ```

  After this is complete, type:

  ```
  $ RUN HAZARD
  ```

- RADC-TR-82-87, *Stress Screening of Electronic Hardware* - This document contains approaches to the development of stress screening program to remove infant mortality of electronic equipment.
- MIL-HDBK-781 (subhead 4.3), *Reliability Test Methods, Plans, and Environments for Engineering development, Qualification, and Production*.
- MIL-HDBK-189, *Reliability Growth Management*.

### 7.7 COMPLETION CRITERIA

Although some elements of PVT are ongoing activities, the Qualification Team must approve the final report and agree that the following criteria, as a minimum, have been met.

- Process control parameters of all major process steps have been documented and the process meets the process specification and all plant-wide Cp/Cpk goals.
- Vendors are meeting the stated goals of the vendor management process.
- An ongoing process control system is in place.
- All PVT failures have been analyzed and dispositions agreed to by the Qualification Team.
- An infancy removal or reduction process is in place, where required, and has been verified to yield a product that meets its goals.
- An initial reliability assessment of production units verifies that the product can meet its reliability requirement.
- Ongoing Reliability Testing (ORT) has started.
- Component qualification is complete for all internally designed products.
- Field return strategy is developed and published.

# 8 RELIABILITY QUALIFICATION TEST (RQT)

The reliability qualification test (RQT) demonstrates that the proposed product meets the reliability requirements stated in the engineering specification.

RQT is a demonstration of the reliability of the product. It is neither a test-analyze-and-fix effort nor a reliability growth exercise. Units that are committed to RQT are expected to perform as if they were shipped to the field and employed in a customer configuration.

## 8.1 GENERAL REQUIREMENTS

The intent of RQT is to demonstrate the reliability of the final design. To ensure this goal is attained, the following requirements have been established.

- At least half the RQT shall consist of units run in a laboratory or test-bed environment.
- At least half the laboratory RQT units will be subjected to the full range of the specification in environmental chambers.
- Units may be run in internal and external field test provided that the units are final design, RQT level units, and provided the validity and consistency of the test data will not be compromised.
- The full reliability requirement, as stated in the engineering specification shall be demonstrated prior to completion of RQT.
- The minimum requirements for demonstration prior to First Revenue Ship (FRS) are:

| Steady-State Reliability Specification | Minimum Demonstration Requirement For | |
|---|---|---|
| | FRS | RQT Complete |
| Less than 50,000 hour MTBF | Full specification | Full specification |
| 50,000 -- 200,000 hour MTBF | 50,000 | Full specification |
| Greater than 200,000 hour MTBF | One fourth the specification | Full specification |

EXAMPLES:

A product with a steady-state specification of 45,000 hours MTBF requires the demonstration of the full 45,000 hours MTBF for both FRS and RQT complete.

A product with a steady-state specification of 150,000 hours MTBF may have an FRS demonstration requirement as low as 50,000 hours MTBF, but must demonstrate 150,000 hours MTBF prior to completion of RQT.

A product with a steady-state specification of 350,000 hours MTBF must have an FRS demonstration requirement of at least 87,500 hours MTBF, and must demonstrate the full 350,000 hour MTBF requirement prior to completion of RQT.

**NOTE**

**These minimum demonstration levels are based on the assumption of aggressive reliability goals and a comprehensive *Six Sigma* design, process development, and DVT effort. They are not intended to preclude higher levels of verification should the situation warrant.**

- Separate RQT goals for announcement, FRS, and completion may be set at the discretion of the Product Management Team as long as these goals comply with the minimum FRS demonstration levels and the demonstration of the full reliability requirement prior to completion of RQT.
- The Qualification Team shall develop the testing strategy to provide the supporting evidence for these milestones.
- PVT data or evidence gathered from other testing, as appropriate, shall be used to aid in the determination as to whether or not the product meets the reliability portion of the engineering specification.

## 8.2 RESPONSIBILITIES

### 8.2.1 Product Management Team

The Product Management Team shall:

- Ensure that the product will meet the reliability requirements as stated in the engineering specification.
- Determine the overall qualification strategy, and to include the demonstration criteria for announcement, FRS, and completion of RQT.
- Approve the RQT plan developed by the Qualification Team.

### 8.2.2 Qualification Team

The Qualification Team shall perform the following tasks.

- Manage the RQT process and develop an RQT plan that reflects the overall qualification and product development plans, including:
  - — Statistical tools to be used for RQT
  - — Hardware configuration(s) for RQT
  - — Software to be run in RQT
- Collect, analyze, and report data, including:
  - — Hold weekly meetings and publish minutes.
  - — Perform reliability analysis as required.
  - — Capture all required data when failures occur.
  - — Maintain supporting data from field test and other CSSE related activities.
  - — Correlate data from manufacturing process qualification testing with RQT laboratory (test bed and chamber) data.
- Establish the definition of relevant and non-relevant failure, and:
  - — Inform responsible organizations, such as Design Engineering of failures.
  - — Ensure that failure analysis is initiated in a timely manner.

- In the event of a reject decision during RQT:
  - — Assess impact of any design changes and ensure appropriate testing.
  - — Drive resolution of failures including the implementation of corrective action.
- Set up and monitor units under test, including:
  - — Ensure diagnostics are sufficient and appropriate for the test.
  - — Maintain logbooks and record data.
  - — Maintain all test equipment throughout the test.
  - — Monitor chamber performance and settings.
  - — Maintain manufacturing history of RQT units.
- Issue the final RQT report.

## 8.3 RQT PLAN

The RQT plan shall be developed by the Qualification Team and shall cover all aspects of the RQT. If separate criteria for announcement, FRS, and RQT completion are part of the Qualification Plan, they shall be treated as stages or phases of RQT and completion criteria for each shall be developed. Policy and procedures for inclusion of field test data and data from other sources shall be included in the RQT plan. The following subheads cover some of the specific areas that shall be covered by the RQT plan. Other topics shall be added as required.

### 8.3.1 Prerequisites

The following requirements shall be completed prior to the beginning of RQT, and shall be listed in the RQT plan.

- The product specification is under ECO control and includes definitive reliability requirements for the product and field replaceable units (FRUs).
- Final reliability apportionment and predictions are complete.
- The design is frozen; that is, no known changes are scheduled prior to FVS or FRS.
- Component qualification is complete.
- DVT is successful and complete.
- Internal field test issues are resolved, such as hardware, software, configuration, diagnostics, firmware, ease of use, and so forth.
- System verification testing has been started and any systematic failures identified and resolved.
- PVT has been started and is progressing according to plan.
- The reliability qualification test plan is approved by the Product Management Team.
- The RQT lab is ready for test start. Lab procedures are available, test equipment calibration and maintenance has been performed, lab personnel responsibilities are defined, and lab personnel training is complete.
- Test-beds and other test equipment are verified to ensure that they are functional.

- Diagnostic and system software to be used in RQT are verified to ensure that product functionality is adequately exercised and evaluated.

### 8.3.2 Statistical Model

The appropriate model for conducting RQT depends on the expected distribution of failures and the desired method of demonstration.

In general, the exponential distribution should be assumed for Storage products. The rationale for this is:

- The product design and process design will have employed the *Six Sigma* philosophy.
- Units used in RQT will be built by Manufacturing during PVT using all infancy removal procedures.
- Units used in RQT shall have undergone testing prior to RQT and any residual infancy will be insignificant and undetectable should it exist.
- Given the relatively short length of RQT, wear out failures are not expected. However, as is true with infant mortality, this assumption should always be verified by analysis of the data collected.

If there is sufficient data to determine that the failure distribution is nonexponential, the appropriate model will be used, and the Qualification Team will analyze the data to determine the reason for the non-exponentiality.

#### 8.3.2.1 Exponential Distribution

For products with an exponential failure distribution, use the Sequential Probability Ratio Test or SPRT (see MIL-HDBK-781 *Reliability Test Methods, Plans, and Environments for Engineering Development, Qualification, and Production* or EL-EN036-00, *Exponential SPRT Generator Specification*). It is an efficient pass/fail test that can be designed to include various levels of both producer and consumer risk. Both references provide the truncated version of the SPRT, which provides for a maximum test length and the advantage of early completion upon acceptance or rejection.

While the SPRT will accept almost any set of parameters, it is recommended that the following SPRT parameters be used:

2:1 discrimination ratio
10 percent to 20 percent producer and consumer risks

#### 8.3.2.2 Non-Exponential Distribution

If the failure data shows other than an exponential distribution the use of the Non-Homogeneous Poisson Process (NHPP) or other Weibull distribution-based tests can be used. The VAX Reliability Tools Suite (VAXRTS) is a Digital software package available for use and is recommended when dealing with non-exponential failure distributions in RQT.

It is not the intent of this document to limit the Qualification Team to only one statistical demonstration model but to encourage the use of different models to help in the assessment of the product's reliability. Note that the reasons for selecting a particular failure distribution must be understood and documented, particularly in the case when non-exponential distributions are used.

### 8.3.3 Failures

All failures, whether they are related to the design, manufacturing process, component, supplier, or workmanship, will be counted. There will be no discounting of failures. If the reject region of the SPRT chart or MTBF analysis from NHPP or Weibull distributions is reached, the test will halt. After failures have been analyzed and corrective action(s) have been determined, implemented, and proven, RQT will start over.

### 8.3.4 Accelerated Testing

Acceleration factors should not be used during RQT unless demonstrated prior to RQT. Full documentation of the derivation of such factors and the rationale for their use shall be included in such cases where the use of acceleration factors is deemed appropriate.

**CAUTION**

**RQT is intended to demonstrate how the product performs when used in the customer's environment. Customers are expected to operate the product within its specified limits, which by definition does not constitute acceleration.**

Acceleration factors, most notably through increased temperature, are not well understood for storage products. Developing RQT strategies with specific acceleration factor assumptions that are not proven could yield results that are significantly different from those that customers will experience.

**NOTE**

**Use of accelerated (high stress) testing in other qualification activities such as DVT and RGT is encouraged, as the purpose of these tests is to precipitate failures so they can be analyzed, understood, and corrected.**

### 8.3.5 Test Administration

- The RQT sample must be built by the (stable) manufacturing process(es).
- The number of units required for RQT will be determined by desired test length, specified reliability, and accept/reject criteria.
- Each electromechanical (disk drive, or tape drive) unit is required to run a minimum of 1000 hours with the exception of units that have failed.

**NOTE**

**If the accept region of the SPRT chart is reached prior to the 1000-hour requirement, units will be required to run and RQT will not be considered complete until the 1000-hour requirement is met. However, plotting on the SPRT chart is not required during this time.**

- Configurations should represent anticipated customer configurations.
- Various types of software shall be used to exercise the product during RQT. This includes the use of diagnostics that provide the best product-specific test coverage, linked with diagnostics that maximize system interaction, along with operating systems and user-environment test programs. It is expected that the software is capable of testing the product to the full range of customer usage (for example, duty cycle).

- RQT units must be tested consistently with all user interaction facets of the engineering specification.

**CAUTION**

**Mechanical insertion/extraction machines simulating user interaction have not been successful in emulating the true user environment or precipitating user induced problems.**

- The product is to be exercised within and to the extremes of its specified parameters, including temperature and humidity. The minimum time at each extreme will be 96 continuous hours.
- The test facilities must be well controlled and highly secure to ensure the integrity of the units under test and the data generated from the test.
- Clear definition of failures, both hard and soft, must be included.
- A reporting matrix describing who receives reports and how disagreement is elevated will be part of the RQT plan.

## 8.4 RECOMMENDED TOOLS

Listed below are some of the tools recommended for use to develop the statistical methodology to be used in RQT.

- MIL STD 781, *Reliability Testing for Engineering Development, Qualification and Production*
- MIL HDBK 781, *Reliability Test Methods, Plans, and Environments for Engineering Development, Qualification, and Production*
- EL-EN036-00, *Environmental SPRT Generator Specification*
- MIL STD 785, *Reliability Program For Systems and Equipment*
- EL-EN036-04, *Hazard (Infancy) Analysis Specification*
- VAX Reliability Tool Suite (VAXRTS)
- "Sequential Testing on the Scale Parameter for the Weibull Case", by Dr. Dimitri Kececioglu. (*Customer Services Peripheral Systems Reliability Seminar Handbook*, May 28-29, 1986)

## 8.5 COMPLETION CRITERIA

RQT will be considered successfully completed when:

- The product demonstrates specified reliability requirement(s) per the chosen statistical methodology
- All failures have been reviewed, categorized, and closed by the Qualification Team
- The Qualification Team unanimously agrees that all required tasks were successfully completed
- The RQT final report is approved by the Qualification Team.

# 9 SOFTWARE AND LAYERED PRODUCTS QUALIFICATION

This heading will be completed at a later date.

# 10 MAINTAINABILITY DEMONSTRATION AND DIAGNOSTICS VERIFICATION

The purpose of the Maintainability Demonstration and Diagnostics Verification (MDT) is to validate the Service Delivery Strategy through verification of the Mean Time to Repair (MTTR) goal, the diagnostics effectiveness goals, and the suitability of the documentation, training, and service delivery tools for installation and maintenance. The objectives of the Maintainability Demonstration are:

- To verify the validity, consistency, accuracy, organization, and adequacy of maintenance manuals, documents, and training, including:
  - How effectively the documentation supports the error information presented by tools, host-based error log, and option internal diagnostics and utilities
  - How well the documentation provided uses or presents information on error rates; for example, based on observed error rates, is it really time to fix something?
  - Identification of any human factors problems associated with the man/machine interface
  - Identification of any process or design changes needed to meet maintainability requirements
  - Determination of whether the maintenance process or equipment or diagnostic design must be improved to meet the stated maintenance (MTTR and maximum repair time) requirements, including:

    How well errors (transient or intermittent) are presented
    How effectively tools handle the error information
  - Verification of improvements after accomplishment of recommended maintenance manual, training, or design changes

This section is applicable to all products subject to the Phase Review Guidelines.

## 10.1 PREREQUISITES

- DVT Fault Insertion (CSSE) is complete.
  - Verify fault coverage goals are met (detection and isolation).
  - Ensure reporting mechanisms are correct (unit and subsystem).
  - Verify diagnostic coverage (internal and external).
- SVT Functional and Fault Management testing is complete.
- Final draft documentation is available.
- Training:
  - Training course is in place.
  - Participants are identified and must have been through the course a minimum of one week prior to MDT commencement.
  - Interactive Troubleshooting Simulator (ITS) is complete.

- Test plan is complete and signed off.
- Equipment:

  RQT level units
  Typical system and subsystem configuration
  Units or options for MDT packaged for shipment to customer prior to MDT
  Sufficient units available to address array, subsystem, and/or add-on configurations
  All special tools and test equipment available
  CD kit defined and available
- Engineering specification is complete, signed off, and contains maintainability goals.
- Diagnostics are available on bootable media as required by system and are part of a full diagnostic package typical of an SDC release.

### 10.2 RESPONSIBILITIES

The Qualification Team is responsible for managing the overall maintainability demonstration process, and, in particular, for ensuring that all prerequisites are met. Specific areas of responsibility are as follows.

- Manufacturing ensures:
  - Delivery of the product as specified in the test plan
  - Resolution of any process problems found during the MDT
  - Provision of FRUs accumulated defective spares for use in the demonstration
- Engineering is responsible for resolution of any design problems found during MDT.
- CSSE:
  - Defines appropriate Customer Service personnel and obtains Field Service commitment for participation.
  - Ensures all resources are available at the time of the MDT, to include:

    Systems
    Spares
    Space
    Tools
    Diagnostics
    People
    Training
    Documentation
  - Writes and signs-off the test plan.
  - Conducts the test.
  - Publishes the final report.
- Customer Service — The field organization must be willing to dedicate the time of field personnel to the maintainability demonstration. Without its support developer the test will not produce a valid estimation of compliance with specified goals. It is particularly necessary to obtain the opinion and advice of the user, as opposed to the inventor, of the training and documentation.

### 10.3 REQUIREMENTS

The MDT shall be sufficient to establish the adequacy of the following.

- Documentation and Training in the areas of:

  Installation
  Troubleshooting
  Remove and replace

- Diagnostics:

  Detection
  Isolation
  Verification

- Specified Maintainability Features:

  MTTR
  Service Delivery Tools (VAXsim, Syserrorlogs, and so forth)

### 10.4 REFERENCE DOCUMENTS

- *Maintainability Demonstration Guide*
- MIL STD 471, *Maintainability Verification/Demonstration/Evaluation*
- MIL STD 472, *Maintainability Predictions*
- Appropriate Customer Service product documentation
- Appropriate product plan

### 10.5 COMPLETION CRITERIA

The Maintainability Demonstration portion of the qualification process shall be considered complete when the Qualification Team agrees that all requirements in the test plan have been completed and the Maintainability Demonstration final report has been issued.

# 11 FIELD TEST

The purpose of field test is to verify that the product meets the customer requirements in the areas of product operation, performance and maintainability. The following should be noted.

- Field test provides product performance information to verify that the product defined in the specification is really the product that meets the needs and expectations of the customer.
- Field test data can be used to supplement both Design Verification Test (DVT) and Reliability Qualification Test (RQT) data.
- Fifty percent field test completion is on the Pricing and Announcement Committee (PAC) checklist for announcement.
- Field test is a key milestone in the Phase Review Process.
- Field test provides product performance information not available from any other source.

Field testing is done in two stages — The first is the Alpha Test which uses prototype hardware or software and is placed in selected internal Digital sites. The Alpha Test is designed to test the product in a user environment. Some of the sites used in the Alpha Test will use the product to qualify their own products with the one being field tested.

The second stage, the Beta Test, is designed to test a more mature product (one that is very close to FRS level) at a selected group of internal and/or external customers. Also, the Beta Test is designed to evaluate all supporting features of the product such as service, documentation, training, packaging and shipping processes, and so forth.

The activities observed during the field test are the following.

- Human interface and ease of operation
- Performance
- Availability and reliability
- System integration and compatibility
- User applications
- Usability, completeness, and accuracy of documentation
- Quality
- Installation and support procedures
- Customer service and support
- Training

## 11.1 FIELD TEST RESPONSIBILITIES

Field test involves the coordination of many different functions and organizations. The major responsibilities are divided among the Product Management Team (Engineering, Manufacturing, Product Management, and CSSE). These responsibilities are as follows.

## 11.2 ALPHA FIELD TEST

### 11.2.1 Alpha Entry Criteria

The minimum criteria for the start of the Alpha Test are as follows.

- An Alpha Test Plan must be written and approved.
- The functional specification must be signed off.
- Predetermined, specified DVT milestones, and levels of quality must have been met.
- A standard IN DEC Customer Service contract must be signed.
- Adequate spares support must be provided.
- Appropriate training must have been conducted.

### 11.2.2 Alpha Completion Criteria

The following are the minimum criteria for completion of the Alpha Field Test.

- All problems reported during the Alpha Test have been closed to the satisfaction of Program Management Team and Qualification Team.
- Documentation has been thoroughly reviewed.
- All sites have been polled for comments.
- A final report is written and distributed to Product Management Team.

## 11.3 BETA FIELD TEST

### 11.3.1 Test Site Selection and Qualification

The Product Manager will formally announce the upcoming field test and request nominations for field test sites. A local account team will make first contact with prospective external test sites. The Product Manager, in conjunction with the Product Management Team, will make the final test site selection. The following are key elements in site selection.

- All parties agree to support field test.

**NOTE**

**All parties include Customer, Sales, Customer Service, Manufacturing, Engineering, CSSE, Product Management, and Legal.**

- The external site organization agrees to sign field test agreements.
- The site organization agrees to the required hardware and software configuration and minimum hardware and software revision levels.
- The site commits to test every component of reasonable configuration of the product in accordance with the Site Test Plan (outlined in Addendum B of the standard Field Test Agreement).
- The site can withstand system failures.
- The system(s) has a Customer Service maintenance contract.
- Adequate local Customer Services support is available for both software and hardware.

- The site agrees to evaluate the product, respond to surveys and questionnaires, and report all problems in the agreed manner.
- The site does not have a critical need for the product.

### 11.3.2 Beta Entry Criteria

The minimum criteria for the start of the Beta Field Test are as follows.

- A Field Test Plan is written and approved.
- The product includes full functionality (to specification).
- Preliminary documentation is available.
- Functionality has been verified in DVT, and the design meets all requirements for entry into RQT.
- The product is fully supported by Customer Service.
- Adequate spares support is provided.

### 11.3.3 Beta Completion Criteria

The following are the minimum criteria for completion of the Beta Field Test.

- Any changes or ECOs made to hardware, firmware, or software that will be included in FRS-level units have been installed and verified at all field test sites.
- All problems reported during field test are closed to the satisfaction of Product Management Team and Qualification Team.
- Documentation is thoroughly reviewed.
- All relevant site personnel are polled for comments.
- A final report is written and distributed to the Product Management Team.

## 11.4 EXTERNAL FIELD TEST SITE LEGAL CONSIDERATIONS

External field test sites shall be chosen based on three primary considerations: the trustworthiness of the owner, the security of the site relative to the Digital equipment, and the technical needs of the field test.

The nature of field test, that is the use of unannounced pre-FRS products by our customers, requires that the Product Management Team be aware of and address many legal requirements. These requirements are listed in the standard Field Test Agreement. The CSSE Licensing group or the appropriate law department can answer questions concerning these requirements. Any modification to the standard Field Test Agreement must be approved by the appropriate law department.

## 11.5 FIELD TEST PLAN

The Product Management Team is responsible for the planning, implementation, and assignment of responsibilities for all field test activities. The Product Manager, with the support of the Product Management Team, is responsible for producing the field test plan for both Alpha and Beta Field Test. The plan should include, as a minimum, the following information.

- Objectives of Alpha and Beta Field Test
- Description of system components and characteristics to be tested
- Reliability data requested
- Prerequisite hardware and software requirements, including documentation
- Recommended number of sites, units, configurations, types of usage, and geographic locations
- Site selection criteria
- CSSE Support Plan
- Spares Support Plan
- Change Process — define responsibilities and process for problem resolution or product upgrade
- Entry and completion criteria
- Responsibilities
- Test results and status reporting
- Test schedule
- Final report requirements

## 11.6 REPORTS

It is vital that periodic, detailed test reports be generated. CSSE will have the responsibility of gathering the data and publishing a biweekly report. This report should include, as a minimum, the following information.

- Test results (performance, problems, product improvement suggestions, and so forth)
- Total product metrics and individual site metrics
- Summary of field test events

A final report summarizing the results will be published by CSSE at the end of field test.

# 12 ONGOING RELIABILITY TEST (ORT)

Ongoing Reliability Tests:

- Measure product reliability as shipped from manufacturing and verifies that products meet the reliability requirements as stated in the engineering specification.
- Verify manufacturing process consistency.
- Provide information and feedback to drive ongoing reliability growth and data for Six Sigma integration.

The requirements in this section apply to all Storage products. In some cases, such as piece parts or internal modules, a full ORT may not be cost effective. In these cases it is the Manufacturing facility is responsibility to implement some form of testing so the results show the ability of the product to meet the Six Sigma goals established by Storage Systems.

## 12.1 PREREQUISITES

ORT is required whenever the product is being produced for customer consumption. However, the following items should be complete prior to ORT start.

- The product specification must be under ECO control and include definitive reliability requirements for the product and FRUs.
- The manufacturing processes are specified, documented, and under revision control.
- All previous qualification testing has been successfully completed or is proceeding according to plan.
- PVT has begun and there are no systemic problems that would impact ORT.
- The ORT plan and procedure have been seen by the Qualification Team and approved by the Product Management Team. In cases where more than one plant manufactures the same product, there is one set of documents developed and agreed upon, driven by the prime plant.
- An ORT team is identified for the purpose of reviewing ORT data and driving corrective action when problems arise.
- ORT test software and hardware are verified to ensure proper exercising of the product under test.
- ORT units meet the latest shippable revision.
- If acceleration factors are to be used, they have been demonstrated, documented and agreed upon by the Qualification Team and the Storage Systems Qualification Steering Committee. In addition, the product engineering specification shall be ECOed to specify the expected reliability at various temperature points.

## 12.2 RESPONSIBILITIES

While it is the responsibility of the Qualification Team to ensure that an effective ORT process is in place, it is the manufacturing facility's responsibility to have a team focused on the day-to-day management of ORT. The team ensures that testing is done in accordance with the product-specific plans and procedures. The ORT team will review all failures, dispose of all failed hardware, determine proper corrective action, and ensure that corrective action is implemented.

The team is composed of individuals from the following organizations.

- Reliability Engineering
- Production
- Quality Engineering
- Manufacturing Engineering
- Design Engineering
- CSSE

Other organizations such as Component Engineering and Supplier Engineering shall participate on an as-needed basis.

At a minimum, the team shall be responsible for:

- Writing ORT plans and procedures
- Providing test equipment and test lab
- Implementing the test per the plan and procedure
- Collecting, analyzing, and reporting data
- Holding weekly meetings and publishing minutes
- Troubleshooting ORT failures (for example, diagnosis to lowest level)
- Repairing and retesting units that fail in ORT in accordance with standard repair procedures
- Tracking and obtaining corrective action on failed subassemblies and components sent for failure analysis
- Initiating design changes for design related failures and pending ECOs
- Initiating process changes for process related failures seen in ORT
- Resolving supplier related failures seen in ORT
- Correlating Field performance with ORT results
- Obtaining and providing process data on all units, including:
  - Process yield data at all identified points in process, so that process data can be correlated with ORT data
  - Specific units that fail in ORT
- Ensuring process changes are implemented as identified
- Providing quality data such as user audit results for correlation with ORT results

## 12.3 REQUIREMENTS

Units that are submitted to ORT are expected to perform as if they had been shipped to the field and used in a customer configuration. All failures shall be logged as of the first occurrence. Non-relevant failures shall not be entered into the data. Failures will be analyzed and resolved by product design, supplier, and/or manufacturing process changes, where appropriate. However, all relevant failures will continue on the record and will be used in calculating the estimated reliability. Countable failures shall not be removed from the data as a result of corrective action.

### 12.3.1 Statistical Demonstration Model

The Sequential Probability Ratio Test (SPRT) will be used to monitor compliance with the reliability specification. This test should serve two purposes: First, protect the customer, to ensure that the product that is accepted by this test has a low risk of not meeting the specified reliability. Second, to trigger corrective action quickly when there is a perceived reliability problem. In order to accomplish both objectives, the following parameters for the SPRT in ongoing reliability testing are recommended.

| | |
|---|---|
| Upper test MTBF, $\theta_0$ : | Product specification |
| Lower test MTBF, $\theta_1$ : | Half of product specification |
| Producer's risk, $\alpha$ : | Twenty percent (.20) |
| Consumer's risk, $\beta$ : | Five percent (.05) |

A monthly point estimate MTBF, which is the total number of test hours accumulated for the month divided by the total number of countable failures, shall be calculated. In the case of products with high MTBF requirements (greater than 50,000-hour MTBF requirements), the MTBF will be determined over a measurement window to be described in the product-specific ORT plan. In cases where no failures are observed, the total hours during the measurement window shall be reported, preceded by a greater than ">" sign.

Acceleration factors can be used if they have been demonstrated. (The initial weeks of testing in ORT can be used to verify acceleration factors through controlled studies.)

### 12.3.2 Test Sample

ORT units are selected off the end of the production line on a weekly basis, or more frequently.

ORT sample sizes are determined by specified product reliability and run-time requirements to demonstrate the intended reliability.

Minimum initial sample sizes should be derived from the following chart.

| Specified MTBF (hours) | Minimum Test Hours | Frequency |
|---|---|---|
| Less than 25K | 3 X MTBF | Monthly |
| 25K—50K | 2 X MTBF | Monthly |
| 50K—100K | 3 X MTBF | Three months |
| Greater than 100K | 3 x MTBF | Six months |

### 12.3.3 Unit Run-Time

Each ORT unit must run a minimum of four weeks. However, under certain circumstances, it may be desirable to run a larger sample for a somewhat shorter period of time. In either case, minimum test hour requirements should be met.

A portion of the ORT sample will be transitioned into life testing for extended testing. See heading 16.

### 12.3.4 Hardware Configurations

Hardware configuration(s) shall be consistent with customer applications. Half the ORT sample should be tested over the full environmental range specified (ORT lab testing). The other half should be tested in a user environment, such as in a cluster environment. A minimum of 30 percent of the total number of ORT units should be fully loaded.

### 12.3.5 Software

Various types of software shall be used to exercise the product during ORT. This process includes the use of diagnostics that provide best product-specific test coverage, linked with diagnostics that maximize system interaction, and with operating systems and user-environment test programs. It is expected that the software is capable of testing the product to the full range of customer usage (for example, duty cycle).

### 12.3.6 User Interaction

ORT units must be tested consistently with all user interaction facets of the engineering specifications.

### 12.3.7 Environmental Conditions

Generally, ORT testing is performed at ambient plant temperature and humidity conditions. It is also recommended that a sample product be run in its specified environmental conditions to ensure that products meet their environmental specifications before they are shipped.

In some cases, such as at the module level, it may be desirable to run ORT in thermal cycle or high-temperature conditions. Those cases should be defined on a product-by-product basis.

### 12.3.8 Failure Definitions

ORT is not intended to be a design or infancy removal effort, but a demonstration that the product will meet customer expectations. The definition of relevant failure should reflect the customer's view of the product, in total, including process problems, design problems, out-of-specification soft error rates, human interaction problems, software problems, and so forth.

Dead on Arrivals (DOAs) consist solely of those units that do not function on power up. They are the only failures that will not count in an MTBF assessment. A DOA rate, however, will be reported for ORT units, and it shall be included in the User Audit DPMU calculations.

### 12.3.9 Reliability Improvement Program

In order for the full reliability potential of each product design to be achieved, there must be an organized reliability improvement program in place. Each product will have a goal (achievable planned value for a defined point in time). At that time, the Specification, Goal, and Performance as shipped are that value. All functions (Engineering, Manufacturing and the Field) will strive for the same goal, and integrated cross-functional plans will be in place to achieve the goal. Meeting the goal is done by tracking failures at the suppliers, in the manufacturing process, in ORT and the field, and by ensuring that permanent corrective action is implemented.

**NOTE**

**Once the product has consistently demonstrated performance at or above goal in ORT and at customer sites, the specification will be updated to reflect the higher reliability requirement.**

### 12.3.10 ORT Plan

The ORT plan must include:

- Prerequisites consistent with this document
- Defined Manufacturing ORT team
- Responsibilities of various functions
- Defined corrective action process
- Definition of failures—both hard and soft
- Data requirements and analysis techniques
- Sampling methodology
- Sample size and run-time requirements
- Test specifics, for example, environment, configuration, software, user interaction, and so forth
- Data analysis procedures to identify any residual infancy
- Procedures to address ongoing burn-in analysis

### 12.3.11 Reporting

It is important that ORT results be reported accurately and in a timely manner. Reports shall be published monthly and shall include:

- All product related failures
- Three month and monthly run-time and number of failures
- Three month MTBF point estimate calculations
- 80 percent confidence intervals (90 percent lower confidence if no failures)
- SPRT status
- Point estimate reliability graphs for major FRUs
- DOA rate and failures
- DPMU rate seen in User's Audit

- Recommendations for ECO/FCO to the manufacturing process or the design based on failure analysis
- Product's manufacturing burn-in period
- Failure rate (MTBF) at the end of the burn-in period
- Burn-in time needed to reach the specified failure rate (MTBF)
- ORT Report distribution shall contain as a minimum the following groups or individuals.
  - — Storage Systems Information Management Group Quality Manager
  - — Customer Plant interface
  - — Customer Plant Quality Manager
  - — Product Qualification Team
  - — ORT Team

## 12.4 RECOMMENDED TOOLS

A description of point estimate is included in the requirements section. The Sequential Probability Ratio Test (SPRT) is discussed in heading 8. EL-EN036-04, *Hazard (Infancy) Analysis Specification* should be used for burn-in analysis.

EL-EN036-00, *Exponential SPRT Generator Specification* should be used to generate SPRT charts with unequal producer's and consumer's risk. To obtain the software online, send ENET mail to CSSE::WHITTEMORE requesting access, then:

```
$COPY CSSE::DISK$A6:[CSSEINFO.RAMP]NEW_SPRT.*;*
  TO: SPRT.*;*
```

To obtain a copy of the specification, send name, mailstop, badge number, cost center, and ENET node to JOKUR::SMC via ENET.

EL-EN036-04 should be used for burn-in analysis.

## 12.5 COMPLETION CRITERIA

ORT, as the name implies, is an ongoing assessment of product reliability. As such, there are no "one time" completion criteria. However, the MTBF must be successfully met each month (or other measurement window defined in the ORT plan).

If at any time the reject zone of the SPRT chart is entered, the following personnel, at a minimum, shall be contacted.

- Plant manager
- CSSE
- Storage Systems Quality

# 13 USER'S AUDIT

The User's Audit (UA) is performed to ensure that the manufacturing processes consistently produce products that conform to or exceed Problem Free Installation (PFI) goals by simulating customer application.

The requirements in this document are to be applied to all storage products.

## 13.1 PREREQUISITES

The following items should be completed or verified prior to the start of User Audit.

- The product specification must be under ECO control and include definitive PFI requirements for the product/FRUs.
- The manufacturing processes are specified, documented, and under revision control.
- All previous qualification testing has been successfully completed or is proceeding according to plan.
- There are no systematic problems that would impact PFI.
- The User's Audit plan and procedure have been approved.
- The User's Audit Qualification Team has been identified and assigned to develop the PFI checklist, review User's Audit data, and drive corrective action when problems arise.
- The PFI checklist has been approved for use by the Product Management Team.
- User Audit software and hardware have been verified to ensure proper exercising of the product under test.
- User Audit units can be obtained from a Finished Goods Source.

## 13.2 RESPONSIBILITIES

The UA Qualification Team focuses on the day-to-day management of User's Audit. The team shall ensure that testing is done in accordance with the product-specific plans and procedures. It shall review all failures, render dispositions on all failed hardware, determine proper corrective action, and ensure corrective action is implemented.

The UA Qualification Team is composed of, but not limited to, individuals from the following organizations.

- Production
- Quality Engineering
- Manufacturing Engineering
- Design Engineering
- CSSE

At a minimum, the team will be responsible for:

- Writing the User's Audit plan, procedures, and checklists
- Providing test equipment and a test lab
- Implementing the test according to plans and procedures

- Collecting, analyzing, and reporting data
- Holding weekly meetings and publishing minutes
- Troubleshooting failures (for example, diagnosis to lowest level)
- Repairing and retesting units that fail in accordance with standard repair procedures
- Tracking and obtaining corrective action on failed subassemblies and components sent for failure analysis
- Initiating process changes for process-related failures seen in User's Audit
- Obtaining and providing process data on all units, including:
  - Process DPU data at all identified points in the process, so that process data can be correlated with User's Audit data
  - Specific units that fail in User's Audit
- Ensuring process changes are implemented as identified
- Providing quality data such as manufacturing final acceptance and field Problem Free Installation (PFI) for correlation with User's Audit data

## 13.3 REQUIREMENTS

Units that are submitted to User's Audit are expected to perform as if they had been shipped to the field and used in a customer configuration. All failures shall be counted from the time of their occurrence. Non-relevant failures shall not be entered into the data. Failures will be analyzed and resolved by product design, supplier, and/or manufacturing process changes, where appropriate. However, all relevant failures will continue on the record and shall be used in calculating performance metrics. Countable failures shall not be removed from the data as a result of corrective action.

### 13.3.1 Measurement Metric

Total Defects Per Million Units (DPMU) will be the metric used in calculating User's Audit performance.

```
DPMU  =  Total Defects per Unit (TDU) x 1,000,000
```

**NOTE**

**DPMU should not be confused with DUPM, Defective Units per Million Units which is the current method of quantifying field installation quality.**

### 13.3.2 Test Sample

- User's Audit units are selected from the appropriate Finished Goods Source on a daily basis.
- Units must be randomly selected.
- Minimum sample size is determined by the UA Qualification Team and should be large enough to demonstrate significant confidence in achieving the PFI DPMU goal.

### 13.3.3 Unit Run Time

Run time is a function of the time required to perform a proper visual/mechanical inspection and run the functional tests that have been agreed to by the UA Qualification Team.

### 13.3.4 Hardware Configurations

Hardware configuration(s) shall be consistent with customer applications.

### 13.3.5 Software

Various types of software shall be used to exercise the product during User's Audit. This includes use of diagnostics that provide the best product-specific test coverage, linked with diagnostics that maximize system interaction, and with operating systems and user-environment test programs.

### 13.3.6 User Interaction

User's Audit units must be tested consistently with all user interaction facets of the engineering specifications.

### 13.3.7 Environmental Conditions

Generally, User's Audit testing will be performed at ambient plant temperature and humidity conditions.

### 13.3.8 Closed Loop Failure Analysis and Corrective Action System

A closed loop failure analysis and corrective action system must be in place to expeditiously identify product and process deficiencies and ensure proper corrective action.

### 13.3.9 Failure Definition

The definition of a relevant failure should reflect the customer's view of the product, in total, to include DOAs, process problems, design problems, out-of-spec error rates, human interaction problems, software problems, and so forth.

A PFI is an installation that has not had any problems that the customer would want resolved before the installation is considered complete by the customer.

### 13.3.10 Problem Free Installation (PFI), Defects Per Million Units (DPMU) Improvement Program

In order for the full potential of each product design to be achieved, there must be an organized PFI improvement program in place. Each product has a goal (achievable planned value for a defined point of time). At that time, the Specification, Goal, and Performance as shipped are that value. All functions (Engineering, Manufacturing and Customer Service) strive for the same goal and integrated cross-functional plans shall be in place to achieve the goal. Meeting the goal is done by tracking failures at the suppliers, in the manufacturing process, in User's Audit and the field, and by ensuring that permanent corrective action is implemented.

**NOTE**

**Once the product has consistently demonstrated performance at or above the goal in User's Audit and at customer sites, the specification is updated to reflect the higher PFI DPMU.**

### 13.3.11 User's Audit Plan

The User's Audit Plan must include:

- Prerequisites consistent with this document
- Defined UA Qualification Team
- Responsibilities of various functions
- Defined corrective action process
- Definition of failures—both hard and soft
- Data requirements and analysis techniques
- Sampling methodology
- Sample size and run-time requirements
- Test specifics, for example, environment, configurations, software, user interaction, and so forth.

### 13.3.12 Reporting

It is important that User's Audit results be reported accurately and in a timely manner. Reports shall be published monthly and shall include:

- All product-related failures for the last 3 months
- Calculated PFI DPMU for the last 3 months
- Corrective action addressing all product-related failures

## 13.4 COMPLETION CRITERIA

User's Audit is an ongoing assessment of product installation performance. There are no "one time" completion criteria. However, each month the PFI DPMU must be successfully met. Any time the performance is below goal, the process described in the requirements section is implemented until performance improves to meet or exceed the goal.

**NOTE**

**A plan to address product phase down needs to be included in the User's Audit plan.**

# 14 POINT OF MANUFACTURE (POM) QUALIFICATION

The intent of this section is to establish Point of Manufacture (POM) qualification of a new product at or prior to FRS within guidelines of *DEC STD 072-0 Corporate POM (Point of Manufacture) Qualification Requirements*.

All new products introduced by Storage Systems *must* be POM qualified. Products are defined as all hardware and software products including upgrades, add-ons, buy-outs and systems marketed by Digital.

## 14.1 PREREQUISITES

The following items are prerequisites to POM qualification.

- A written product focus POM qualification plan, by function and phase
- A review matrix from Phase 0 to FRS
- A POM maintenance strategy

## 14.2 RESPONSIBILITIES

The Manufacturing plant POM manager is responsible for the product POM qualification plan. The plan shall be agreed to and approved by the Product Management Team.

The plan POM Manager establishes and provides POM qualification review criteria to the phase review team leader.

Maintenance of POM strategy for any follow-on product variations is the responsibility of the plant POM Manager.

## 14.3 REQUIREMENTS

### 14.3.1 Product POM Qualification Plan

The POM Qualification Plan is written by the plant quality manager and approved by the engineering and manufacturing members of the Product Management Team by Phase 0 exit.

As a minimum, the plan covers the following. Refer to DEC STD 072-0.

- Requirements by function, for example, engineering, manufacturing, material sourcing, order administration, and system plant
- Assigned responsibilities
- Assigned schedule (start and completion)
- Schedule relation with product phase cycle

The review matrix is extracted from the POM product plan. However, it will be structured for Phases 0, 1, 2, and 3.

POM maintenance is directed by the POM checklist found in DEC STD 072-0. The POM Project Plan contains, as a minimum:

- A plan for POM testing at Systems Integration Engineering (SIE) (or comparable) test lab
- An order administration readiness review
- All necessary product qualification steps
- A distribution plan

## 14.4 APPLICABLE DOCUMENTS

- *DEC STD 072-0 Corporate POM (Point of Manufacture) Qualification Requirements*
- *Corporate Phase Review Process Guide*, (EL-CP356-00)

## 14.5 COMPLETION CRITERIA

- Risk assessment review with plant POM Manager, Manufacturing System Owner, Order Administration, POM Program Office.
- Acceptance by System Owners onto their POM menu.

# 15 SPARES AND REPAIR PROCESS QUALIFICATION

Spares and repair process qualification ensures that all storage spares consistently comply with all requirements of the engineering specification. This process describes, in detail, the requirements to develop and qualify the repair processes to ensure that repaired and refurbished spares comply with Fit For Use (FFU) requirements. It also describes the information feedback requirements necessary for product improvement.

This process applies to *all* Storage Systems spares, specifically: new spares manufactured by Digital or its suppliers and spares repaired/refurbished by Digital or its suppliers.

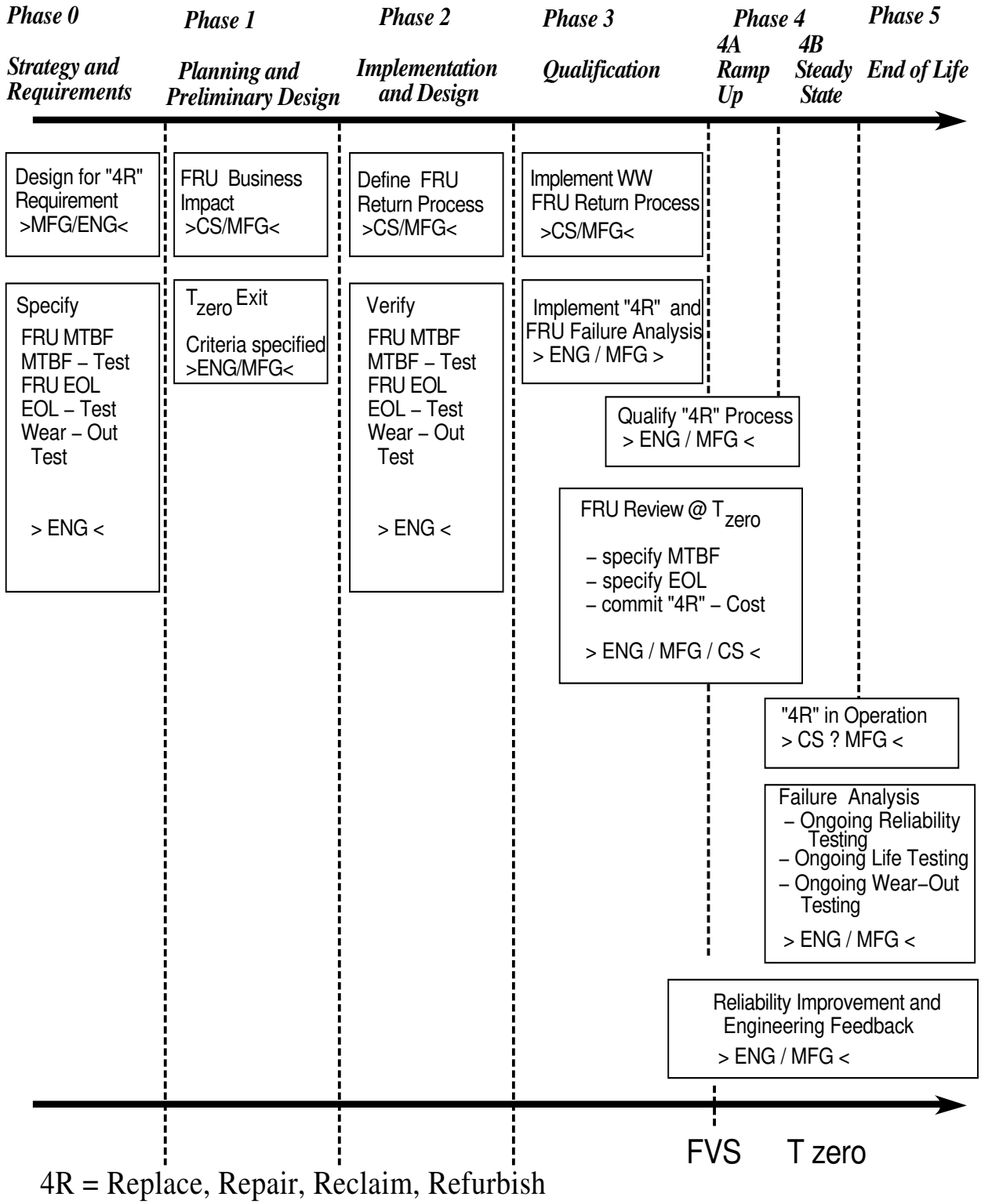
A general procedure for the development/qualification of the spare/repair process is shown in Figure 4.

## 15.1 PREREQUISITES

Complete engineering specification that complies with all applicable Digital standards, to include, as a minimum:

- Reliability specifications for all FRUs and subassemblies (DEC STD 009-2)
- Bar Code Labeling [EL-FS047-00, *Bar Code Labeling Requirements for Field Service Logistics (FSL) Spare Parts*, and *DEC STD 047-0 Bar Code Symbology Criteria*]
- Packaging Requirements per Customer Service Logistics (CSL) Individual Packaging Specification
- The supplier New Build and/or Repair, which is certified in accordance with EL-MF521-00, *Supplier Management Program Introduction*

**Figure 4: FRU/FSR Phase Review Process**



## 15.2 RESPONSIBILITIES

Design Engineering:

- Ensures compliance with DEC STD 009-2 and that the engineering specification is sufficient with respect to FRUs to enable new build and repair process compliance with all appropriate Digital standards.
- Develops ECOs, as needed, to ensure ongoing process and product improvement through the product service life.
- Identifies spares for inclusion in the detailed failure analysis process and life test analysis.
- Defines special tools and test procedures.
- Assists manufacturing and CSL in the design of the new build and/or repair process, and in development of the process qualification plan.
- Keeps CSL and Manufacturing informed of any required or recommended changes in testing due to ECOs or failure analysis.

Manufacturing:

- In conjunction with design engineering and CSL, develops a comprehensive and cost effective new build and repair process specification.
- Develops the new build and repair process qualification plan in conjunction with engineering, CSSE, and CSL.
- Leads development of FRU-return process from customer to manufacturing.
- Ensures compliance with this section of the qualification manual for all FRUs produced or repaired within the manufacturing organization.
- Establishes a process for providing selected spares returned for repair to life test analysis or detailed failure analysis.
- Provides repair data for and ensures compatibility with the CSL data collection system.
- Notifies CSL of any repair process or testing changes.

CSSE:

- Ensures that design engineering develops FRU specifications detailing functional reliability and environmental requirements so that FFU requirements can be determined.
- Ensures that components of FRUs that are subject to wear-out and/or shelf life restrictions are clearly identified in the engineering documentation.
- Influences design engineering and manufacturing to design repairability into products and processes to optimize recycling of spares without degradation of fitness for use.
- Ensures that the customer service plan identifies the repair and data analysis requirements for spares.
- Ensures that the customer service plan identifies a generic format for data collection that is compatible with the CSL data base.

- Identifies, in conjunction with engineering and CSL, those spares that shall be included in life testing analysis and the detailed failure analysis process.
- Ensures FSL and manufacturing have sufficient information to project potential repair process volumes.
- Establishes a process for returning selected spares for life testing analysis.
- Compiles failure analysis trends and works with design engineering (and manufacturing and CSL where appropriate) on possible design improvements to eliminate the weakest areas or problem areas of a particular design.

CSL:

- Develops and maintains, in conjunction with design engineering, CSSE and manufacturing, a comprehensive/cost effective repair process specification for all FRU repair processes.
- Ensures that all non-manufacturing new build and repair process specifications, internal and external, comply with the requirements of the developed process plan, this qualification manual, and all applicable Digital standards.
- Collects and makes available all repair data from CSL repair processes and is responsible for integrating repair data from manufacturing repair processes in a single data base.
- Approves all repair process plans.
- Ensures sourcing of spares only from certified suppliers who have successfully qualified their new build and repair processes.
- Ensures that all parts used in the new build and/or repair process, and those procured as replacement consumables, are in complete compliance with the current engineering specification.

  All components should be purchased from vendors on the Approved Vendor List (AVL), but as a minimum, must be purchased from a qualified vendor per the corporate QVL.
- Manages exception returns, the return of new build and/or repaired spares from the field to the supplier for failure analysis.
- Notifies Manufacturing of any changes required to the repair process testing procedures.

The product Qualification Team ensures that all prerequisites are met, that the process and qualification plans are complete, and all requirements of this section of the qualification manual are met prior to FRS.

### 15.3 REQUIREMENTS

Document Review—The Qualification Team ensures that each of the required documents for phase transition supports the spares process plan, whether new build or repair.

Process Specification—The FRU process specification shall be developed during Phase 2 (DEC STD 028-0) and shall be a complete, detailed description of the intended process. The specification shall include, as a minimum:

Full product technical requirements:

Manufacturing
Repair and refurbish

Manufacturing and/or repair assembly/test process and flow, clearly identifying:

Full functional testing
Infancy removal
ORT strategy
Measurement
Failure data
Individual packaging
Barcoding
Properly identified

- Technical operator certification capability, based on technical need: SMT, TAB, MSL, and so on
- The FRU performance requirements (functional and RAMP)
- Materials handling/identification process
- The ECO/FCO process
- ESD/RFI/safety
- Test Equipment calibration requirements and repair equipment maintenance requirements
- A process for returning samples for life and detailed failure analysis
- Special requirements such as stress testing, shock, voltage/current margining and timing
- The scrapping process
- Product safety and regulatory requirements
- Implementation of all applicable Digital standards to ensure workmanship

The qualification plan shall be developed to assess the capability of the repair process to consistently deliver a spare that meets all aspects of the engineering specification, and shall be consistent with other sections of this document.

Data Collection—Failure data at the FRU level shall be collected by the source.

- Failure data should clearly define components replaced as a result of ECO/upgrade versus Symptom Directed Diagnostics (SDD) or test diagnostic failure.
- Provisions for the collection of no-problem-found data must be made for analysis of root cause and corrective action.
- Failure Data on Field Spares that are not being repaired, still must be collected and analyzed for continuous product improvement.

### 15.3.1 Infancy Removal

New Build Spares—All FRUs provided as new build shall undergo an infancy removal process resulting in reliability levels that match or exceed those of the same part embedded in higher assemblies that are subjected to further testing prior to shipment.

Repair Process Spares—All FRUs intended for field use that have undergone any ECO upgrade and/or repair shall be subjected to an infancy removal requirement. The objective of this requirement is to ensure that the installation of replacement components does not introduce a condition that would prevent the FRU from meeting the reliability requirements of its engineering specification.

### 15.3.2 Wearout

The repair process shall include:

- Identifying and replacing any FRU components that are subject to wear out
- Controlling infancy as a result of such replacement
- Controlling the cumulative reliability degradation or wearout of the FRU or portions of it, as a result of excessive or repeated repairs.

### 15.3.3 Audit

An audit process shall be established and shall be capable of assessing, as a minimum, that:

- The documentation and data collection systems are functioning properly.
- Correct revisions of software and documentation are archived.
- Controls for limiting the number of repair cycles are in place and operative.
- Controls for handling FRU displays of No-Problem Found or Field Preventive Maintenance error codes are in place and operative.
- Documentation and software being used in the repair process are of the latest revision.
- All steps in the repair process are being conducted in accordance with the repair process specification.
- All hardware/interface equipment is in good functional working condition and calibrated in accordance with the calibration schedule.
- All repair documentation is in a good, readable, usable condition and is in ESD safe binders.

## 15.4 REFERENCE DOCUMENTS

These documents shall be consulted during the development, implementation, and qualification of a repair process:

- EL-SM265-00, *Digital Repair Process and Procedures*
- *DEC STD 012-0 Part Identification Standard*
- *DEC STD 030-6 Module Manufacturing Standard—Module Testability Rules*
- *DEC STD 043-0 Packaging Requirements for Digital Products, Parts, Assemblies, and Materials*

- *DEC STD 067-0 Electrostatic Discharge-Sensitive Devices*
- *DEC STD 068-0 Policy for Documentation of Revision Levels of Units and Combinations of Units*
- *DEC STD 116-0 Workmanship Standards Manual—Introduction*

## 15.5 COMPLETION CRITERIA

When all action in the Process Qualification Plan is complete and audited, and the results are documented in a formal qualification report, the repair and spares qualification shall be considered complete.

# 16 LIFE TESTING

Life testing evaluates the long-term failure and wear characteristics of Digital products and subassemblies. Life testing improves the design for reliability process of each new product and manufacturing process through the knowledge gained from planned, controlled, and documented life testing. It also predicts field behavior and helps in the development of product service strategies and tactics that will maintain customer satisfaction throughout the life cycle while maximizing Digital's profitability.

The goal of life testing is to determine that the design and manufacturing processes produce a product that meets all of its design specifications for reliability, life cycle cost, and life expectancy. Life testing also provides early warning of any unforeseen early wearout or non-random failure mode and increases the corporate knowledge of wearout phenomena, environmental impact on useful life, and methods for conducting accelerated life testing.

Life testing is applicable to all storage products and subassemblies that may operate in a potentially hostile (non-benign) environment, or that may exhibit failure modes that historically have been shown to be non-random.

## 16.1 PREREQUISITES

- A complete engineering specification that includes the wearout (life) requirements for all components and subassemblies expected to exhibit a non-random, increasing failure rate during the useful life (including the identification of consumables and the planned maintenance intervals for replacement)
- A complete assessment of all environmental, electrical, and mechanical stress levels to which the product may be exposed
- A life test plan

## 16.2 RESPONSIBILITIES

Design Engineering:

- Assists Manufacturing in the development of the life test plan.
- Defines any special tools or procedures required for tear down and analysis.
- Provides the technical assistance for tear down and failure analysis.
- Establishes wearout specifications that support the Product Business Plan, the Customer Services Service Strategy, and the marketing requirements.
- Designs the product to meet all aspects of the reliability specifications, including the wearout and non-random failure rate portions.
- Proposes design changes for failure modes requiring corrective action.
- Keeps CSL and Manufacturing informed of any required or recommended changes in testing due to ECOs or failure analysis.

Manufacturing:

- Coordinates the development of the life test requirements and writes the life test plan.
- Establishes the tear down and failure analysis team.
- Provides sample units for testing.

- Establishes the tear down and failure analysis process.
- Provides (when applicable) samples of returned spares for tear down and wear analysis.
- Establishes a comprehensive data analysis and reporting procedure.
- Runs the life test.
- Monitors, documents, and communicates the progress and results of the tests.
- Monitors, documents, and communicates the results of failure analysis performed as a result of life testing. Notifies CSL of any repair process or testing changes.

CSSE:

- Participates in the development of the life test plan.
- Establishes procedures with Customer Service Logistics to return failed spares to quality/engineering for tear down.
- Establishes a process with Customer Service to return selected spares directly to the life test failure analysis team for detailed analysis during the initial phases of field introduction and upon the detection of any potential wearout problems.
- Establishes a process for:

– Routinely evaluates field performance and conducts field failure modes analysis
– Tracking the field population for signs of wearout
– Selecting returned Customer Service spares for tear down and inspection for wear

### 16.3 REQUIREMENTS

Subassemblies—Life testing shall be conducted on all FRUs and subassemblies (heads, media, and so forth) that fall within the defined scope of the test.

Process—The life test shall be conducted throughout the life of the product. Additionally:

- Products used in the life testing process will remain in test for their entire operational life or until the Product Management Team agrees that the product-specific life test can be stopped (for example, the product is no longer in production, there are other products that can provide the data, and so forth).
- Products will be added to the process at set intervals and when ECOs, manufacturing process changes, or vendor process/material changes are introduced into the production process.
- Products that fail during life test will have failures logged and will undergo in-depth failure analysis to determine the root cause of the failure. They will be repaired, if feasible, and returned to test.
- A portion of the sample shall be removed from test at specified intervals for tear down and analysis. These units should be returned to testing, if feasible.

Test Plan—The test plan shall completely define the life test process for the product or subassembly under test. As a minimum, the life test plan shall include:

- The test team organization and responsibilities
- A complete set of requirements and expected performance data

- Test sample size and requirements for additional units
- Expected and potential stress levels
- Test stress levels
- Documentation of verification of any acceleration factors used in testing or assessing performance
- Procedures for and action to be taken with regard to returning spares from the field
- Test bed and test procedures, in detail
- Monitoring procedures
- Process to be followed to tear down and analyze the units including:

  Skills needed for personnel
  ESD considerations
  Safety requirements
  Work environment
  Data collection
  Measurement techniques
  Documentation
  Tools required

- Rebuilding process
- Removal and replacement procedures
- Procedures for phase out at completion of production runs and continuation through end of life
- Reporting procedures

### 16.4 COMPLETION CRITERIA

Life testing is an ongoing requirement throughout the product's life. Life testing shall continue until the Product Management Team determines that it is no longer required, but in no case prior to transition to Phase 5.

# 17 BUYOUT QUALIFICATION

Buyout Qualification defines the Qualification Process that Storage Information Management External Products and Technology group uses to procure products, and it ensures that the requirements and objectives of this document are met or exceeded.

This section applies to all externally procured Storage and Information Systems products, subassemblies, hardware, and software.

## 17.1 DEFINITIONS AND CLASSIFICATIONS

A buyout-type product is any product or part of a product (with the exception of components; that is, resistors, ICs, capacitors, and so forth, that are addressed in heading 3 of this document), specified and purchased by Digital that is designed and/or manufactured by an external Digital supplier.

There are three classes of buyouts:

- A fully-customized buyout is designed by Digital and manufactured by an external Digital supplier exclusively for Digital (Class I).
- A semi-customized buyout is designed by Digital and manufactured by an external Digital supplier. This is a non-standard product for the supplier, and it may encompass changes to form, fit, function, and finish (Class II).
- An off-the-shelf buyout is the supplier's standard product, involving no changes to functionality. It may encompass changes for cosmetic purposes *only*, such as logo, and other "trade dress" (Class III).

## 17.2 METHODOLOGY

Externally purchased Storage and Information Management Group Products shall meet or exceed the requirements of all Digital internal qualifications as outlined in heading 2 through heading 16. However, these sections or their detailed applications may vary for a product based on:

- Response to market needs
- Digital's acceptance of supplier's qualification process, level of quality, reliability, and technology.

To support qualification requirements, specific testing and data provided by the supplier may differ from that which would be performed in a typical internally designed Digital product. These differences may be as a result of supplier's variations in the qualification processes, but will meet or exceed requirements.

When specific test and test data differ from stated goals, and objectives (heading 2 through heading 16), Digital will supplement with additional testing or impose additional testing requirements on suppliers.

## 17.3 RESPONSIBILITIES

The Digital Buyout Qualification Team shall develop plans and execute such plans to meet the requirements of each phase of product qualifications.

The qualification will be managed by the Digital Qualification Teams with use of the guidelines of heading 2 through heading 16 with appropriate applicable details.

## 17.4 RECOMMENDED TOOLS

- Storage and Information Management Group Qualification Manual
- Basic Order Agreement (BOA)
- Digital standards
- Phase Review Process

## 17.5 COMPLETION CRITERIA

- Requirements of the qualification process defined in heading 2 through heading 16 are met.
- Successful and timely phase transitions
- Achievement of product quality and reliability goals as defined in the BOA.

# APPENDIX A REFERENCED DOCUMENTS

## A.1 EL-Class Digital Documents

| EL-Class Number | Document Title |
|---|---|
| EL-00002-00 | *DEC STD 002-0 AC Power Wiring, Safety Earth Grounding, Plugs and Receptacle Information and Requirements* |
| EL-00005-00 | *DEC STD 005-0 Operational Alert (OPAL) Procedure* |
| EL-00009-00 | *DEC STD 009-0 Project Specification* |
| EL-00009-01 | *DEC STD 009-1 Product Engineering Specifications: Electrical, Physical, and Environmental Parameters* |
| EL-00009-02 | *DEC STD 009-2 Product Engineering Specifications: Reliability, Availability, and Maintainability Parameters* |
| EL-00012-00 | *DEC STD 012-0 Part Identification Standard* |
| EL-00012-02 | *DEC STD 012-2 Unified Numbering Code for Part Identifier Class Codes* |
| EL-00028-00 | *DEC STD 028-0 Phase Review Policy* |
| EL-00030-00 | *DEC STD 030-0 Module Manufacturing Standard - Introduction and General Information* |
| EL-00030-06 | *DEC STD 030-6 Module Manufacturing Standard - Module Testability Rules* |
| EL-00032-00 | *DEC STD 032-0 VAX Architecture Standard* |
| EL-00038-00 | *DEC STD 038-0 System Evaluation of New Products - General* |
| EL-00043-00 | *DEC STD 043-0 Packaging Requirements for Digital Products, Parts, Assemblies, and Materials* |
| EL-00047-00 | *DEC STD 047-0 Bar Code Symbology Criteria* |
| EL-00052-00 | *DEC STD 052-0 Operational Requirements for Serial Terminals and Computer Interfaces Operating as DTEs Connected to EIA RS-232-C or CCITT V.28 Modems* |
| EL-00056-00 | *DEC STD 056-0 Circuit Diagrams and Item Designations - General Requirements* |
| EL-00057-00 | *DEC STD 057-0 VAXBI Standard* |
| EL-00060-00 | *DEC STD 060-0 Design of Hardware Products to National and International Regulations and Standards, Policies and Procedures* |
| EL-00062-00 | *DEC STD 062-0 Product Submittal to Regulatory Agencies* |
| EL-00062-02 | *DEC STD 062-2 German EMI Certification/Approval Process* |
| EL-00067-00 | *DEC STD 067-0 Electrostatic Discharge - Sensitive Devices* |
| EL-00068-00 | *DEC STD 068-0 Policy for Documentation of Revision Levels of Units and Combinations of Units* |
| EL-00072-00 | *DEC STD 072-0 Corporate POM (Point of Manufacture) Qualification Requirements* |
| EL-00085-00 | *DEC STD 085-0 Component Qualification - Requirements to Support Phase Review Process* |
| EL-00091-00 | *DEC STD 091-0 Product RAMP Requirements* |
| EL-00102-00 | *DEC STD 102-0 Environmental Standard for Computers and Peripherals - General Test Requirements* |

| EL-Class Number | Document Title |
|---|---|
| EL-00103-00 | *DEC STD 103-0 Electromagnetic Compatibility (EMC) - Overview and Process Requirements* |
| EL-00104-00 | *DEC STD 104-0 Product Acoustic Noise Limits* |
| EL-00116-00 | *DEC STD 116-0 Workmanship Standards Manual - Introduction* |
| EL-00119-00 | *DEC STD 119-0 Digital Product Safety - Introduction and General Requirements* |
| EL-00120-00 | *DEC STD 120-0 Product Thermal Design Standard: Design Requirements* |
| EL-00122-00 | *DEC STD 122-0 AC Power Line Standard: Design Requirements and Guidelines* |
| EL-00123-00 | *DEC STD 123-0 Power Control Bus Standard* |
| EL-00158-00 | *DEC STD 158-0 Unibus Specification - Design Specification* |
| EL-00160-00 | *DEC STD 160-0 LSI-11 Bus Specification - Design Specification* |
| EL-00161-00 | *DEC STD 161-0 Computer Interconnect Specification* |
| EL-00178-00 | *DEC STD 178-0 Digital Identification Marking Requirements - Introduction* |
| EL-00186-00 | *DEC STD 186-0 Signal Integrity* |
| EL-CP356-00 | *Corporate Phase Review Process Guide* |
| EL-EN036-00 | *Environmental SPRT Generator Specification* |
| EL-EN036-04 | *Hazard (Infancy) Analysis Specification* |
| EL-FS047-00 | *Bar Code Labeling Requirements for Field Service Logistics (FSL) Spare Parts* |
| EL-MF347-00 | *Ship-to-Stock Supplier Qualification Program - Audit Guideline for Plant Quality Engineer* |
| EL-MF521-00 | *Supplier Management Program Introduction* |
| EL-SM265-00 | *Digital Repair Process and Procedures* |
| EL-SM475-02 | *Engineering Product Compliance Standards and Related Documents - Volume 2* |

Use VTX SMC to order copies of EL-class documents from Standards and Methods Control. Send distribution questions to JOKUR::SMC or call DTN: 234-4423.

## A.2 Other Digital Documents

| Document Number | Document Title |
|---|---|
| NO ORDER NUMBER | *"Sequential Testing on the Scale Parameter for the Weibull Case", by Dr. Dimitri Kececioglu. (Customer Services Peripheral Systems Reliability Seminar Handbook , May 28 - 29, 1986)* |
| | *VAX Reliability Tool Suite* |

## A.3 Other Documents

| Document Number | Document Title |
|---|---|
| MIL STD 471 | *Maintainability Verification/Demonstration/Evaluation* |
| MIL STD 472 | *Maintainability Predictions* |
| MIL STD 781 | *Reliability Testing for Engineering Development, Qualification, and Production* |
| MIL STD 785 | *Reliability Program for Systems and Development* |
| MIL-HDBK-189 | *Reliability Growth Management* |

| Document Number | Document Title |
|---|---|
| MIL-HDBK-781 | *Reliability Test Methods, Plans, and Environments for Engineering Development, Qualification, and Production* |
| RADC-TR-82-87 | *Stress Screening of Electronic Hardware* |

## A.4 Ordering Information

Following are the sources for documents not available from Standards and Methods Control.

- Federal Standards and Military Standards:

  Naval Publications and and Forms Center
  5801 Tabor Avenue
  Philadelphia, PA 19120

- To obtain copies of the *Customer Services Peripheral Systems Reliability Seminar Handbook* and the *VAX Reliability Tool Suite*, contact Dick Leonhardt.

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